Section 206- Flood Plain Management Services Program

SOUTHEAST AREA DRAINAGE DISTRICT STUDY, EAST PROVIDENCE, RHODE ISLAND

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13. ABSTRACT *(Maximum 200 words)*

This study has been conducted under the Corps of Engineers' Section 206 Floodplain Management Services Program. The purpose of this investigation is to evaluate surface water flooding problems along the Annawomscutt Brook and perform a hydrologic and hydraulic analysis of the brook for both existing conditions and with proposed drainage improvements.

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Executive Summary

The Corps of Engineers was requested by the City of East Providence, Rhode Island to conduct an investigation of flooding problems in the city's Southeast Area Drainage District, particularly in the area of Annawomscutt Brook. This study was conducted under the Corps of Engineers Flood Plain Management Services (FPMS) program, authorized under Section 206 of the Flood Control Act of 1960 (PL-86-645). A previous study was conducted for the city in 1981 by Camp Dresser & McKee (CDM), Inc., (Southeast Area Drainage District Report on Drainage Improvements, June 1981) which outlined a series of recommendations to address the most immediate and severe street and basement flooding in the area.

The purpose of this study is to evaluate surface water flooding problems along the Annawomscutt Brook and to analyze the improvements previously recommended by CDM. In particular, the City desires a hydrologic and hydraulic analysis of Annawomscutt Brook for both the existing conditions and with the proposed drainage improvements previously recommended in the CDM report.

There are several problems associated with the Southeast Area Drainage District and Annawomscutt Brook including relatively frequent street flooding during and after heavy rains. This includes flooding of backyards, basements, and in some instances road crossings.

The Annawomscutt Brook watershed has a total drainage area of about 1,237 acres (1.94 square miles) at its outlet to Drown Cove. This includes 884 acres in East Providence (72%) and 353 acres in Barrington (28%). The estimated population of the East Providence portion of the watershed is 4,000 people, based on 1990 census data. The watershed for the Annawomscutt Brook was divided into five subareas for the purpose of this analysis (see Plate 1). Complete subarea descriptions are provided in Appendix A.

Appendix A, the hydrologic and hydraulic analysis, describes in detail the approach used to analyze the flooding problems along Annawomscutt Brook. Water surface profiles were developed for the existing channel of the Annawomscutt Brook. A number of adjustments, such as cleaning the channel and increasing culvert sizes were entered into the

model and analyzed for their effects on water surface profiles. In addition, channel improvements and rerouting of surface waters, as proposed by CDM, were analyzed.

Water surface profiles for the existing and improved conditions of Annawomscutt Brook are shown on Plates 4 and 5, respectively in Appendix A. Table 2 of the main report lists elevations of the channel, structures, top of road crossings along the reach, and water surface elevations. The analysis has determined that most of the culverts along Annawomscutt Brook are undersized. Furthermore, culverts at Haines Park Road and Promenade Street in Barrington, as well as the south access road at the Almac's parking area, Legion Way, Glenrose Drive, and Rounds Avenue in East Providence all have capacities less than the peak runoff from a 2-year event.

Many flow structures along Annawomscutt Brook are undersized and increase the possibility of overtopping of channel banks and roads during rainfall events. Therefore, the alternatives investigated in this study focused on the reduction of overtopping of roads crossing the brook

The most hydraulically effective of the analyzed alternatives appears to be the channel improvements proposed by CDM in conjunction with replacing the culverts at the north and south access roads in the Almac's parking area. Furthermore, although the model does not indicate a significant reduction in water surface elevation due to channel cleaning, it is logical to assume that freeing the channel and culverts from debris and vegetation would aid in the conveyance of flow. Therefore, it is suggested that the city initiate a general maintenance program to mitigate continuing problems.

An updated preliminary cost estimate has also been developed to reflect the original estimate provided in the CDM report of June 1981. These preliminary estimates are for planning purposes only.

The recommended plan is to:

- replace existing culverts with twin 4'x4' reinforced concrete box culverts at the Circuit Drive extension, Rounds Avenue, and the south access road in the shopping plaza north of Willett Avenue;

- replace existing culverts with twin 5'x5' reinforced concrete box culverts at Glenrose Drive and Legion Way;

- replace existing culverts with twin 6'x6' reinforced concrete box culverts at the north access road to the shopping plaza north of Willett Avenue.

and,

- reconfigure the existing brook from Meadowcrest School to Willett Avenue by lowering the invert elevation an average of 3.5' and regrading the side slopes. The existing invert elevation at Willett Avenue will remain.

For severe storm events, the improvements modeled do not exhibit a marked reduction of overtopping of the channel banks at the Almac's parking area or from Willett Avenue through Haines Park Road in Barrington. Table 2 shows that for the improved conditions, the flooding problem is completely resolved for rainfall events of a 2-year frequency or smaller. Flooding still occurs for storms greater than the 2-year rainfall event.

The preliminary cost estimate for the recommended plan is $322,000 and is detailed in Table 3 of the main report.

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I. INTRODUCTION

1. Study Background

The Corps of Engineers was requested by the City of East Providence, Rhode Island to conduct an investigation of flooding problems in the city's Southeast Area Drainage District. This study focused only on the surface water flooding problems of Annawomscutt Brook, which is the major water course through the Southeast Area Drainage District. A study conducted for the city in 1981 by Camp Dresser & McKee (CDM), Inc., (Southeast Area Drainage District Report On Drainage Improvements, June 1981) outlined a series of recommendations to address the immediate and most severe street and basement flooding within the Southeast Area Drainage District, including the Annawomscutt Brook watershed. However, the city has requested an analysis of the hydrologic and hydraulic conditions of Annawomscutt Brook before implementation of any further drainage improvements. Plate 1 shows the limits of the study area.

2. Study Authority

This study was conducted under the Corps of Engineers' Flood Plain Management Services (FPMS) program. The FPMS program, authorized under Section 206 of the Flood Control Act of 1960 (PL-86-645), allows the Corps to provide planning and technical assistance related to flooding and flood plain management.

3. Study Purpose & Scope

The purpose of this study is to evaluate surface water flooding problems along the Annawomscutt Brook and to analyze the improvements previously recommended by CDM. In particular, the city desires a hydrologic and hydraulic analysis of Annawomscutt Brook for

both the existing conditions and with the proposed drainage improvements previously recommended within the CDM report. The complete Scope of Studies is contained in Appendix C. All elevations given in this report are referred to the East Providence datum, which is 2.35' above the National Geodetic Vertical Datum (NGVD).

4. Other Pertinent Studies

1) East Providence Comprehensive Plan; Prepared for the City of East Providence by BRW, Inc.; 1992

2) Comprehensive Site Assessment Work Plan - East Providence Terminal; Volumes I and II; Prepared for Mobil Oil Corporation by Roux Associates; December 1993

II. PROBLEM IDENTIFICATION

The problems associated with the Southeast Area Drainage District and the Annawomscutt Brook area have been previously documented in the CDM report and in the East Providence Comprehensive Plan. An outline of these problems is provided below.

There are several problems associated with the Southeast Area Drainage District and Annawomscutt Brook. These include relatively frequent street flooding from surface runoff and flow in Annawomscutt Brook and basement flooding of residential areas due to high groundwater. However, the groundwater issue does not impact the surface water flood analysis and is not addressed further in this study.

In addition, the East Providence Comprehensive Plan defines a Southeast Drainage District Critical Area. This Critical Area is actually the northern portion of the Southeast Drainage District as identified in the CDM report. It extends roughly from Meadowcrest Drive east to the Wampanoag Trail, and from Forbes Street south to Rounds Avenue. The Comprehensive Plan also identifies a development strategy which is for very low intensity development due to both wetlands and the closed Forbes Street Landfill. According to the Comprehensive Plan, the Critical Area shares the same problems as the rest of the Southeast Area Drainage District. This includes a high groundwater table, relatively flat terrain, and overall poor drainage.

The city experiences surface water flooding problems associated with Annawomscutt Brook, particularly during heavy rainfall events. This includes flooding of backyards and in some instances road crossings. Hydraulic analyses were performed for three historic rainfall events - November 18, 1994, August 19, 1991 (Hurricane Bob), and July 17, 1989 and this information was then provided to the City of East Providence. Flooding areas were identified by comparing the calculated water levels with the existing bank crest and/or road elevations. Areas that had calculated water levels higher than the existing bank or road

elevations were considered "flooded". The results of these analyses of Annawomscutt Brook were found to correlate with reports of flooding maintained by the city. The November 1994 and Hurricane Bob events produced water levels associated with a less than 2-year event with virtually no flooding. The July 1989 event produced water levels similar to a 5-year frequency rainfall. Based on calculated water surface elevations at various road crossings in East Providence, the following areas are flooded during a 2-year rainfall event: (1) the north and south access roads at the Almac's parking lot; (2) Legion Way; and (3) Glenrose Avenue. The severity and number of locations of flooding increases for a 25-year rainfall event. The water surface elevations for 2, 5, 10, and 25-year frequency rainfall events are shown in Appendix A. The differences between the existing conditions and the recommended improvment conditions are more fully discussed in Chapter IV.

The city is also concerned about the impacts of further drainage improvements as recommended in the CDM report of June 1981. Either improving the existing drainage system or adding to it may change the flow characteristics of the brook. The city wanted to investigate the hydraulic capacity of the brook and its present ability to receive stormwater discharges from varying rainfall frequency events.

III. EXISTING CONDITIONS

1. General Watershed Description

The Southeast Area Drainage District is approximately 855 acres in size and is bordered by Forbes Street on the north, Estrell Drive on the east, Willett Avenue on the west and Willett Avenue and the East Providence-Barrington municipal boundary on the south. However, the Southeast Area Drainage District does not cover the entire Annawomscutt Brook watershed (see Plate 1). This study focuses on the problems associated with surface water flooding associated with the Annawomscutt Brook. For purposes of conducting the hydrologic and hydraulic analyses of the brook, the entire Annawomscutt Brook watershed, extending to Drown Cove in Barrington, was utilized. Therefore, the limit of the model used for this study is the entire Annawomscutt Brook watershed including about 353 acres in Barrington and about 96 acres north of Forbes Street in Mobil Oil Corporation's bulk storage facility. These areas are not specifically within the Southeast Area Drainage District. Plate 1 shows the boundaries of both the Annawomscutt Brook watershed and the Southeast Area Drainage District. Below is a brief description of the watershed and it's characteristics. A more detailed description is provided in Appendix A.

The entire Annawomscutt Brook watershed covers about 1,237 acres. This includes 884 acres in East Providence (72%) and 353 acres in Barrington (28%). The estimated population of the East Providence portion of the watershed is 4,000 people, based on 1990 census data. Land use within the East Providence portion of the watershed is characterized in the following manner: Residential (43%); Open Space, including parks, the Forbes Street landfill, and undeveloped portions of the Mobil facility (40%); Public/Semi-Public, including the Meadowcrest and Waddington Elementary Schools (7%); Commercial, including the shopping plaza along Willet Avenue (2%); and Industrial, comprising the developed portions of the Mobil facility (8%).

The Annawomscutt Brook watershed in East Providence is characterized principally by open space in its northern and central sections with the remaining area primarily single-family residential dwellings. The majority of residential land usage occurs between Rounds Avenue and the Barrington town line. The open space includes mostly undeveloped woody and swampy areas of Mobil Oil Corporation's bulk storage facility and the closed Forbes Street Landfill. The Forbes Street Landfill was operated by the City of East Providence between 1969 and 1979 and consists of approximately 67 acres located north and east of the Meadowcrest Elementary School.

About 96 acres of the Annawomscutt watershed are located in the Mobil facility's South Operations Area north of Forbes Street. This part of the Mobil property is further subdivided into four sections: the Storage Tank Farm, the Main Refinery, the Binder Platform, and the Acid Treatment Area. Portions of each of these sections are located within the Annawomscutt Brook watershed. This includes many current and former structures associated with the operation of the refinery. This part of the watershed also includes large portions of open space and undeveloped land consisting mostly of marshy and wooded land. These areas drain through natural watercourses to a channel leading into a 30" reinforced concrete pipe under Forbes Street, eventually becoming part of Annawomscutt Brook.

The portion of the Annawomscutt Brook watershed in Barrington contains a mix of residential land use, open space (Haines Memorial State Park), and industrial and commercial areas along Bay Spring Avenue. This area also contains large ponds formed by hydraulic constrictions such as the stone masonry culvert in the former railroad embankment near Bay Spring Avenue and a small dam and weir at the brook's outlet into Drown Cove.

2. Annawomscutt Brook Description

Annawomscutt Brook is formed by the wetlands in the northerly section of the Southeast Area Drainage District in the vicinity of the former Forbes Street Landfill and also by the wetlands located on Mobil Oil's facility north of Forbes Street (See Plate 1). Two

open channels drain the Forbes Street area which includes the former Forbes Street Landfill and the portion of the watershed extending north of Forbes Street into Mobil Oil Company's bulk storage facility. The main channel of Annawomscutt Brook begins east of Abraham Road and continues south, passing just east of the Meadowcrest Elementary School. At this point it is joined by a second open channel which originates at Forbes Street and drains the wetlands located on Mobil's property through a 30" diameter concrete culvert passing under Forbes Street. This second channel drains the upper portions of the watershed including the Mobil facility and extends south from Forbes Street to the Meadowcrest Elementary School Access Road before passing into an 24" diameter concrete inlet pipe. A smaller drainage ditch also discharges to this channel (see Photo 1) just prior to entering the 24" pipe. This pipe continues behind the houses on Griffith Drive, eventually discharging to an approximately 500' long open channel south of the school. The channel continues east before joining the main Annawomscutt Brook channel. The area through which these channels pass is primarily undeveloped woody and swampy land south of Forbes Street which also contains the former landfill.

The brook continues in a southerly direction until reaching the area of Thurston and MacArthur Streets. At this point the channel is about 8' wide and turns about 90° (see Photo 2) to the east. The City has excavated a secondary channel which extends in a southerly direction and apparently carries excess surface runoff during periods of heavy precipitation and snowmelt runoff. However, the invert elevation of this secondary channel is slightly higher and it appears that during periods of low or normal flow, the brook follows the main channel to the east. After continuing east for approximately 650', the main channel turns 90° to the south and flows about 450' to another channel which extends west (at a 90° angle from the main channel) back towards the secondary flow channel described above. This configuration can be seen on Plate 1 and Photo 4. However, the brook's low flow path continues another 400' south before entering a 48" diameter concrete pipe (see Photo 5) located behind the residence at the corner of Tanglewood Drive and Rounds Avenue.

The secondary flow channel excavated by East Providence proceeds from the

Thurston Street area about 800' south before passing under Rounds Avenue through two 30" diameter corrugated metal pipes (see Photos 3 and 6). Downstream of these culverts the channel invert and side slopes are paved with asphalt for approximately 900' (see Photo 7). This channel continues south eventually entering a 24" diameter culvert under Glenrose Drive. It then discharges on the south side of Glenrose Drive through a 30" diameter outlet pipe (see Photo 8).

As previously mentioned, the normal flow path for Annawomscutt Brook enters a 48" diameter concrete pipe into the local storm drain pipe network. The underground network proceeds west along the south side of Rounds Avenue and then south behind the residences on Ferncrest Drive to Glenrose Drive. The drainage network eventually discharges through two 36" diameter concrete pipes at Glenrose Drive (see Photo 9). Approximately 70' south of Glenrose Drive the main Annawomscutt Brook channel exiting the stormwater pipe network and the secondary channel recombine. The channel is about 6' wide at this location and continues south between the houses on Ferncrest Drive and the Waddington Elementary School (see Photo 10) before passing through a 42" diameter concrete pipe culvert under Legion Way (see Photo 11).

Annawomscutt Brook then flows south through a shopping plaza and commercial land use area. The brook runs directly through the plaza's parking lot with two access roads crossing the brook between both sides of the lot. The channel is about 10' wide in this area. At the northerly crossing the brook passes through two 72" corrugated metal pipe culverts. The west culvert is partially blocked by sediment and vegetation (see Photos 12 and 13). At the southerly access road crossing the brook passes through two 36" pipe culverts. The western 36" pipe appears to be constructed of different types of pipe. The upstream end is corrugated metal and the downstream end is reinforced concrete (see Photo 14). The brook then flows south through a 5' by 12' concrete box culvert under Route 103, Willett Avenue (see Photo 15) and continues into Barrington. It flows through the backyards of a primarily residential area with only one street crossing, a 42" diameter concrete pipe culvert at Promenade Street (see Photo 16).

The brook then continues south to Haines Park Road passing through three 24" diameter corrugated metal pipe culverts (see Photo 19). South of Haines Park Road, the brook enters a large pond within Haines Memorial State Park, northeast of a former railroad embankment which is now a bike path. The pond's outlet is an approximately 4-foot by 2-foot stone masonry culvert (see Photos 21 and 22) through the former railroad embankment leading to another pond just north of Bay Spring Avenue. There is an estimated 60" diameter corrugated metal pipe culvert under Bay Spring Avenue (see Photo 23) leading to a pond and small dam/weir outlet structure. The dam structure forms the downstream limit of Annawomscutt Brook and also appears to be the limit of tidal influence from Narragansett Bay. The brook passes over this structure and enters Drown Cove in Narragansett Bay (see Photo 24).

Refer to Appendix B for a general description of each of the major culverts along Annawomscutt Brook.

IV. HYDROLOGIC & HYDRAULIC ANALYSIS

1. Introduction

a. General. The Annawomscutt Brook has a total drainage area of about 1.94 square miles at the outlet to Drown Cove. Due to the extremely small size of the brook and the corresponding watershed, there is no recorded hydrologic information pertaining to Annawomscutt Brook. The watershed for the Annawomscutt Brook was divided into five subareas for the purpose of this analysis (see Plate 1). The subarea delineation differs slightly from CDM's analysis and includes a subarea, BA1, in the Town of Barrington. Complete subarea descriptions are provided in Appendix A.

2. Study Procedure

a. General. Appendix A describes in detail the approach used to analyze the flooding problems along Annawomscutt Brook. The U.S. Army Corps of Engineers Hydrologic Engineering Center's HEC-1, "Flood Hydrograph Package", was utilized to develop flood hydrographs. The peak flows from the hydrographs were subsequently applied to the Corps' HEC-2, "Water Surface Profiles".

b. Rainfall Runoff Hydrograph Development. Due to the lack of hydrologic information pertaining to Annawomscutt Brook, peak flow rates in the brook had to be estimated utilizing the U.S. Department of Agriculture Natural Resources Conservation Service (NRCS) Runoff Curve Number Method within HEC-1. Drainage areas, curve numbers, and lag times for the NRCS Method were determined based on U.S. Geological Survey (USGS) quadrangles, NRCS soil survey of Rhode Island, and information in CDM's Report on Drainage Improvements.

Rainfall for the 2, 5, 10, 25, and 50-year, 24-hour events, as shown in Table 1, was applied to the watershed model. Runoff from each sub-basin was routed downstream to the brook outlet at Drown Cove. The results of this analysis are presented in Appendix A - Table 3, which lists index stations and peak runoff rates for the different frequencies analyzed.

TABLE 1

RAINFALL FREQUENCY DURATION
USWB TECHNICAL PAPER 40
EAST PROVIDENCE, RHODE ISLAND
(INCHES)

Annual Frequency		Duration in Hours				
Percent	Year	1	2	6	12	24
50	2	1.2	1.6	2.3	2.7	3.3
20	5	1.6	2.1	2.9	3.5	4.2
10	10	2.0	2.5	3.5	4.1	4.9
4	25	2.2	2.9	4.0	4.9	5.5
2	50	2.6	3.2	4.3	5.2	6.2

c. Water Surface Profile Development. Once a number of synthetic storm hydrographs were developed, and peak discharges established for points along the brook, water surface profiles were computed utilizing HEC-2. In an attempt to validate the entire model, three historical storm events were evaluated. The water surface profiles developed for the three events (November 18, 1994; August 19, 1991 (Hurricane Bob); and, July 17, 1989), which were smaller than the synthetic 2-year storm, were compared to flooding logs kept by the City of East Providence. No deviation was exhibited between the modeled results and actual historic records.

3. Analysis Results

a. General. Water surface profiles were developed for the existing channel of the Annawomscutt Brook. A number of adjustments, such as cleaning the channel and increasing culvert sizes were entered into the model. In addition, channel improvements and rerouting of surface waters, as proposed by CDM, were analyzed.

b. Existing Conditions. Water surface profiles for the existing conditions of Annawomscutt Brook are shown in Appendix A - Plate 4 for the 2, 5, 10, and 25 year synthetic storms. Table 2 lists elevations of the channel, top of road crossings along the reach, and water surface elevations at the same locations as shown in Appendix A - Plate 4. The profiles demonstrate that most of the culverts along Annawomscutt Brook are under-sized. Furthermore, culverts at Haines Park Road and Promenade Street in Barrington, as well as the south access road at the Almac's parking area, Legion Way, Glenrose Drive, and Rounds Avenue in East Providence all have capacities less than the peak runoff from a 2-year event.

The most upstream cross section on the profiles represents a point just north of the intersection between the easterly bend and the excavated channel. Continuing the HEC-2 model further upstream would not impart any useful information since the brook travels through woodlands and the Forbes Street Landfill.

c. Alternative Proposals

(1) Clean Channel

Reconnaissance visits to Annawomscutt Brook revealed that the channel is not well maintained in some areas. In particular, the embankments in the Almac's parking area and the west bank along the Waddington School contain an excess of brush, and in some

instances, the channel is not aligned with the culverts. The culverts at Promenade Street, the Almac's parking area, and Legion Way also have silt accumulated along their inverts.

The HEC-2 model was set up to represent the existing channel without vegetation along the embankments or silt within the culverts. Parameters within the model were modified to represent a dragline-excavated or dredged channel with no vegetation. In general, water surface elevations changed by no more than 0.5 foot anywhere along the channel versus existing conditions.

(2) Increase Culvert Sizes

A series of increased culvert sizes were modeled to evaluate their effectiveness in reducing water surface elevations, particularly within East Providence. These included the following scenarios:

i. Resizing the stone masonry culvert at the bike path in Barrington with two different culvert alternatives was accomplished. A 6-foot diameter corrugated metal culvert and twin 5-foot by 5-foot box culverts were each input into the model at the bike path. However, there was no significant effect upstream in East Providence due to increasing the size of the culvert at the bike path. This is due to hydraulic constrictions at the Promenade Street crossing.

ii. With the twin box culverts at the bike path, backwater effects to Promenade Street were now the result of the restriction of the Bay Spring Avenue culvert. Another twin 5-foot by 5-foot box culvert was placed into the model to replace the Bay Spring Avenue culvert. Again, minimal effects were observed in East Providence even with new larger culverts at both the bike path and under Bay Spring Avenue in Barrington. Again this is apparently due to hydraulic constrictions at Promenade Street.

iii. The model was then setup to investigate possible culvert changes at Promenade

Street. Returning the downstream culverts at the bike path and Bay Spring Avenue to their actual sizes, the Promenade Street culvert was replaced in the model with twin 5-foot by 5-foot box culverts. The results show that for the 2-year and 5-year rainfall events, there will be slightly less overtopping of the south access road in the Almac's parking lot. Further upstream of the parking area, however, there is no impact from enlarging the Promenade Street culvert.

iv. Due to siltation in the channel, the culvert inverts at the north and south access roads in the Almac's parking area are located below the stream bed elevation. Also, the twin 36 inch culverts at the south access road are well undersized. The model was run with these two sets of culverts enlarged and brought up to the stream bed elevation. The south culverts were replaced by twin 4-foot by 4-foot box culverts, and the north culverts were replaced by twin 6-foot by 6-foot box culverts. Water surface elevations decreased by about one foot in the channel for a 2-year event. Water surface elevations for events between the 2-year and 10-year storms were lower than with the existing culverts, by a few inches, and there was no effect on the 25-year event. Water surface elevations upstream at Legion Way were not affected by enlarging the north and south access road culverts.

(3) Proposed Channel Reconfiguration and Culvert Resizing

The CDM report of June 1981 recommended lowering and reshaping Annawomscutt Brook between the Meadow Crest School and Willett Avenue, and constructing twin 4-foot by 4-foot concrete box culverts near the Circuit Drive extension and at Rounds Avenue, and 5-foot by 5-foot concrete box culverts at Glenrose Drive and Legion Way. The new channel bottom width would vary between 8 and 10 feet with a side slope of 2 horizontal to 1 vertical. These CDM proposed channel improvements were input into the HEC-2 model. The CDM report also recommended that the brook be kept in its natural state between the Meadow Crest School and Forbes Street.

The most significant effects of the proposed changes were the lowering of water

surface elevations at Legion Way and Glenrose Drive by as much as 1.5 feet for the 25-year storm event and 2.5 feet for the 2-year event. The new culverts at these locations prevented overtopping of these roads in the model.

Because these culvert changes were upstream of the Almac's parking area reach, the culverts at the access roads were also increased to twin 4-foot and twin 6-foot box culverts as described in paragraph 3.c.2.iv. Due to these further improvements, the resulting water surface elevations at Glenrose Drive and Legion Way were lowered by another few inches, and the water surface elevation between the north and south access roads was lowered by another 0.8 feet for the 2-year event and half a foot for the 5-year storm. For larger storms, however, effects of this modification on the model were minimal. Appendix A - Table 8 shows the anticipated effects on the East Providence water surface profile if CDM's improvements and improvements at the Almac's parking area are constructed. Appendix A - Plate 5 displays the water surface profiles and the improved brook invert.

Changes in the proposed sizes of box culverts at Legion Way, Glenrose Drive, and Rounds Avenue were analyzed. For a 25-year storm event and existing topography, the 5-foot by 5-foot twin box culverts at Glenrose Drive and Legion Way and the 4-foot by 4-foot twin box culverts at Rounds Avenue appear to be the optimal sizes.

(4) Diversion of Watershed Area EP1

Another alternative suggested by CDM and analyzed in this report involves diverting stormwater runoff originating from the watershed subarea north of Forbes Street out of the Annawomscutt Brook watershed and into Willett Pond to the southwest. However, runoff from subarea EP1 does not appear to contribute significantly to peak flows in Annawomscutt Brook and was therefore not given further consideration.

TABLE 2 - ESTIMATED WATER SURFACE ELEVATIONS
EXISTING CONDITIONS VS. RECOMMENDED IMPROVEMENTS

Cross Section	Location	Location Elevation	EXISTING 2-Yr. Event	EXISTING Flooding (Water Elev. - Bank Elev)	IMPROVED 2-Yr. Event	IMPROVED Flooding (Water Elev. - Bank Elev)	EXISTING 25-Yr. Event	EXISTING Flooding (Water Elev. - Bank Elev)	IMPROVED 25-Yr. Event	IMPROVED Flooding (Water Elev. - Bank Elev)
Willett Avenue (upstream end)	Top of East Bank	17.12	13.78	-3.34	13.8	-3.32	16.61	-0.51	16.62	-0.5
	Top of West Bank	19.14	13.78	-5.36	13.8	-5.34	16.61	-2.53	16.62	-2.52
	Road Elev.	18.97	13.78	-5.19	13.8	-5.17	16.61	-2.36	16.62	-2.35
South Access Rd. (upstream end)	Top of East Bank	15.06	15.1	0.04	14.11	-1.95	16.8	1.74	16.93	0.87
	Top of West Bank	15.2	15.1	-0.1	14.11	-2.09	16.8	1.6	16.93	0.73
	Road Elev.	14.78	15.1	0.32	14.11	-1.67	16.8	2.02	16.93	1.15
North Access Rd. (upstream end)	Top of East Bank	15.06	15.17	0.11	14.22	-1.84	17.22	2.16	17.3	1.24
	Top of West Bank	15.2	15.17	-0.03	14.22	-1.98	17.22	2.02	17.3	1.1
	Road Elev.	16.69	15.17	-1.52	14.22	-3.47	17.22	0.53	17.3	-0.39
Legion Way (upstream end)	Top of East Bank	18.42	17.88	-0.54	14.85	-3.57	18.63	0.21	18	-0.42
	Top of West Bank	17.84	17.88	0.04	14.85	-2.99	18.63	0.79	18	0.16
	Road Elev.	18.3	17.88	-0.42	14.85	-3.45	18.63	0.33	18	-0.3
Glenrose Avenue (downstream end)	Top of East Bank	17.88	18.17	0.29	15.53	-2.35	19.49	1.61	18.32	0.44
	Top of West Bank	18.88	18.17	-0.71	15.53	-3.35	19.49	0.61	18.32	-0.56
	Road Elev.	19.67	18.17	-1.5	15.53	-4.14	19.49	-0.18	18.32	-1.35
Rounds Avenue (downstream end)	Top of East Bank	21.77	no flow	***	18.23	-3.54	20.8	-0.97	19.36	-2.41
	Top of West Bank	23.37	no flow	***	18.23	-5.14	20.8	-2.57	19.36	-4.01
	Road Elev.	23.15	no flow	***	18.23	-4.92	20.8	-2.35	19.36	-3.79

Note: 1. All elevations given in East Providence datum. 2. A box indicates flooding occurs at that location.

V. CONCLUSIONS & RECOMMENDATIONS

1. Conclusions

Many existing drainage structures along Annawomscutt Brook are undersized and increase the possibility of overtopping of channel banks and roads during rainfall events. The alternatives investigated in this study focused on the reduction of overtopping of roads crossing the brook. Table 2 shows existing top of bank and roadway elevations as well as water surface elevations for both existing conditions and with the recommended improvements in place.

The most hydraulically effective of the analyzed alternatives appears to be the channel improvements proposed by CDM in conjunction with replacing the culverts at the north and south access roads in the Almac's parking area. For severe storm events, the improvements modeled do not exhibit a marked reduction of overtopping of the channel banks at the Almac's parking area or from Willett Avenue through Haines Park Road in Barrington. Table 2 shows that for the improved conditions, the flooding problem is completely resolved for rainfall events of a 2-year frequency or smaller. Flooding still occurs for storms greater than the 2-year rainfall event.

The lowering of the water surface elevation in East Providence due to channel improvements represents a loss of storage within those improved reaches. Although the hydraulic model was not run to account for any increase in downstream discharge due to channel improvements in East Providence, the amount of stage reduction and resulting loss of storage should not significantly increase discharge rates in the Barrington reach.

2. Recommendations

Although the model does not indicate a significant reduction in water surface elevation due to channel cleaning, it is logical to assume that freeing the channel and culverts from debris and vegetation would aid in the conveyance of flow. Channel velocities within the East Providence reach of Annawomscutt Brook generally range between 1 feet per second (ft/s) to 3 ft/s, which may facilitate sediment deposition, especially at high flow rates. It is suggested that the city of East Providence consider cleaning the brook channel and implementing a routine maintenance program for areas of Annawomscutt Brook not already routinely cleaned. This will improve the conveyance of runoff from small storms as well as the aesthetic quality of the brook. In summary, the recommended plan is to:

- replace existing culverts with twin 4'x4' reinforced concrete box culverts at the Circuit Drive extension, Rounds Avenue, and the south access road in the shopping plaza north of Willett Avenue;

- replace existing culverts with twin 5'x5' reinforced concrete box culverts at Glenrose Drive and Legion Way;

- replace existing culverts with twin 6'x6' reinforced concrete box culverts at the north access road to the shopping plaza north of Willett Avenue.

and,

- reconfigure the existing brook from Meadowcrest School to Willett Avenue by lowering the invert elevation an average of 3.5' and regrading the side slopes. The existing invert elevation at Willett Avenue will remain.

Table 2 shows water surface elevations resulting from the impementation of these recommended improvements. Model results indicate that flooding as a result of a 2-year rainfall event can be eliminated by implementing the recommended improvements. Flooding from a 25-year rainfall event can also be significantly decreased throughout East Providence

through the implementation of the recommended improvements.

An updated preliminary cost estimate has also been developed to reflect the original estimate provided in the CDM report of June 1981. The construction costs presented here are based on the preliminary costs developed by CDM in June 1981 and have been updated to 1995 prices using the October 1995 Engineering News Record (ENR) Construction Cost Index of 5511. CDM had originally used a Construction Cost Index of 3450 from April 1981. These preliminary estimates are for planning purposes only. The recommended plan and preliminary cost estimates are presented in Table 3.

TABLE 3
ESTIMATED CONSTRUCTION COSTS OF
RECOMMENDED IMPROVEMENTS

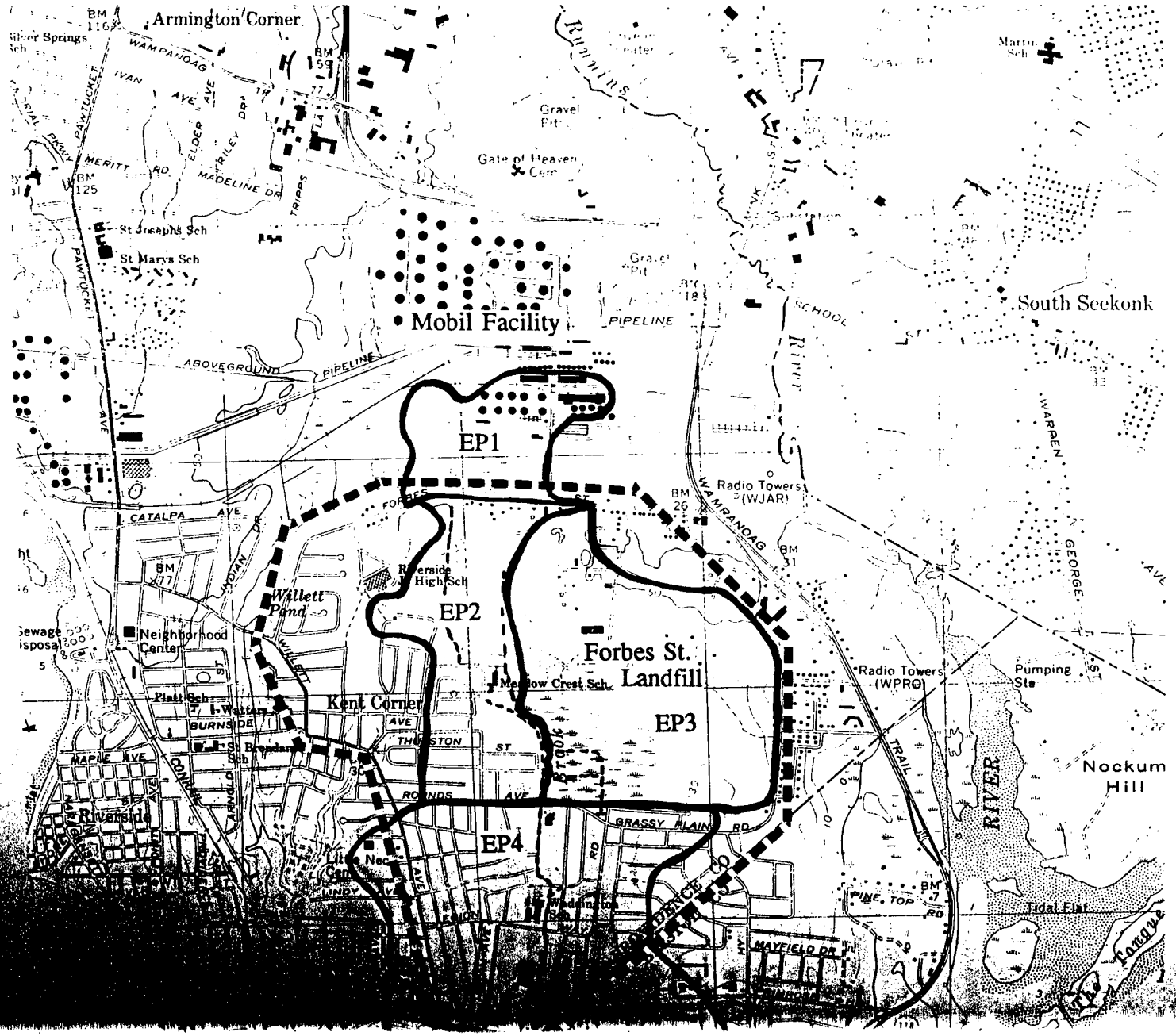
	Item	Estimated Cost
1.	Lowering Channel Invert between Meadow Crest School and Willett Avenue	$96,000
2.	Twin 4'-0" Concrete Box Culverts	
	▸ Circuit Drive extension	$32,000
	▸ Rounds Avenue	$32,000
	▸ South access road	$32,000
3.	Twin 5'-0" Concrete Box Culverts	
	▸ Glenrose Drive	$40,000
	▸ Legion Way	$40,000
4.	Twin 6'-0" Concrete Box Culverts	
	▸ North access road	$50,000
		$322,000

VI. ACKNOWLEDGEMENTS

This report was developed and prepared by John Kedzierski, P.E., Project Manager. The hydrologic and hydraulic analyses were performed by David Margolis, Water Control Division. The report was prepared under the supervision and management of the following New England Division personnel:

Colonel Earle C. Richardson, Division Engineer
Joseph L. Ignazio, Director of Planning
John C. Craig, Chief, Formulation Division
John R. Kennelly, Chief, Special Studies Branch

Information, data, and assistance was provided by the following City of East Providence personnel: Daniel A. Pennington, City Engineer, and Steven Durfee, Department of Public Works.


Armington Corner
Mobil Facility
EP1
EP2
EP3
EP4
Forbes St.
Landfill
South Seekonk
Kent Corner
Riverside
Willett
Pond
Neighborhood
Center
Riverside
High Sch
Meadow Crest Sch
Radio Towers
(WJAR)
Radio Towers
(WPRO)
Pumping
Ste
Nockum
Hill
Tidal Flat
Gravel
Pit
Gate of Heaven
Cem
St Josephs Sch
St Marys Sch
Martin
Sch
Platt Sch
St Brendans
Sch
Little Nec
Cem
Meadowlark
Sch
ABOVEGROUND
PIPELINE
PIPELINE
WAMPANOAG
TRAIL
FORBES
CATALPA
AVE
MAPLE AVE
BURNSIDE
AVE
THURSTON
ST
ROUNDS
AVE
GRASSY PLAIN
RD
PINE TOP
RD
MAYFIELD DR
WARREN
AVE
GEORGE
AVE
SCHOOL
ST
PAWTUCKET
AVE
MERITT
RD
MADELINE DR
TRIPPS
IVAN
AVE
ELDER
AVE
TRILEY
DR
CONRAD
AVE
ARNOLD
AVE
WILLETT
ST
INDIAN
DR
RUNNINS
RIVER
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BM
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BM
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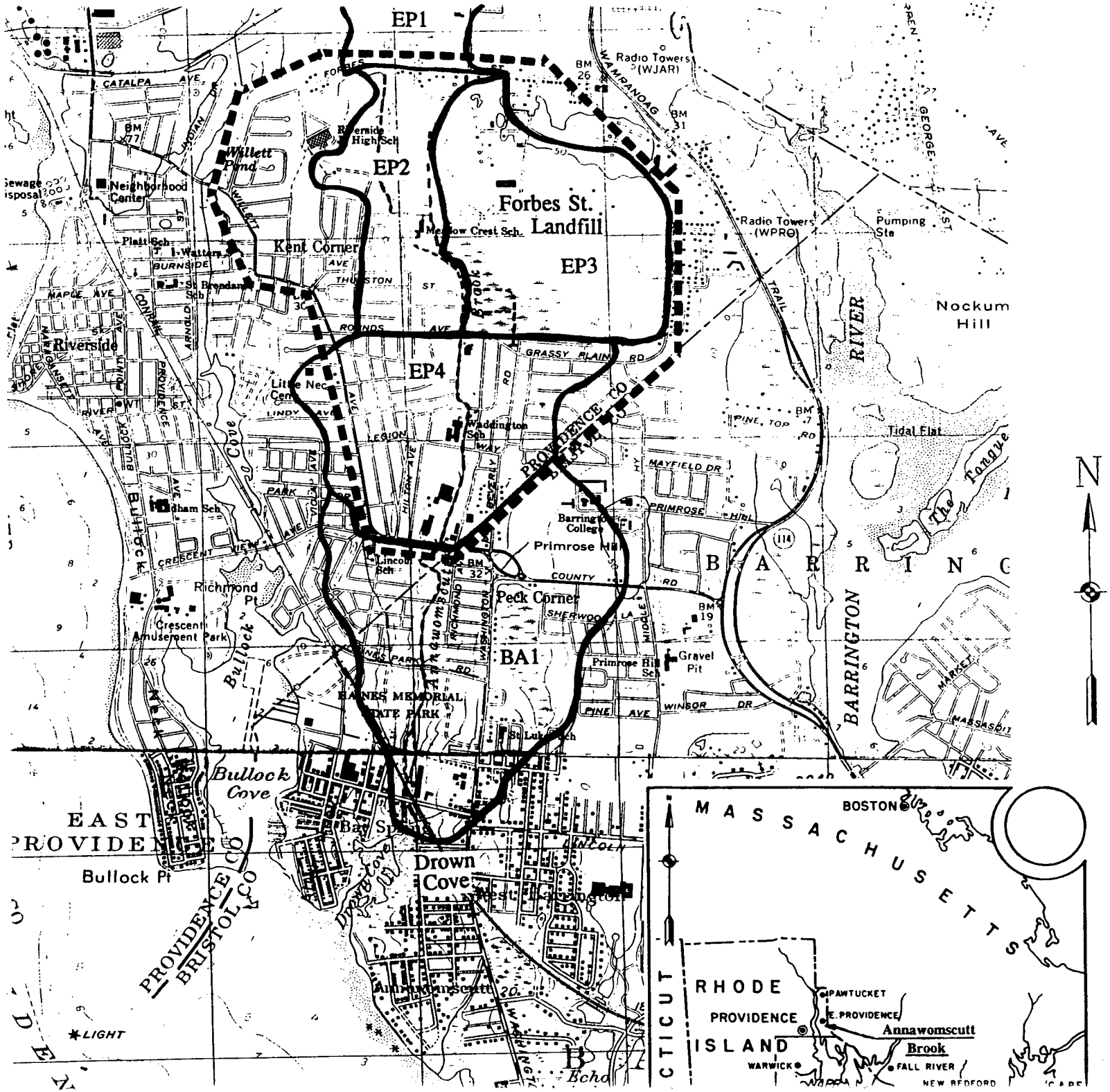
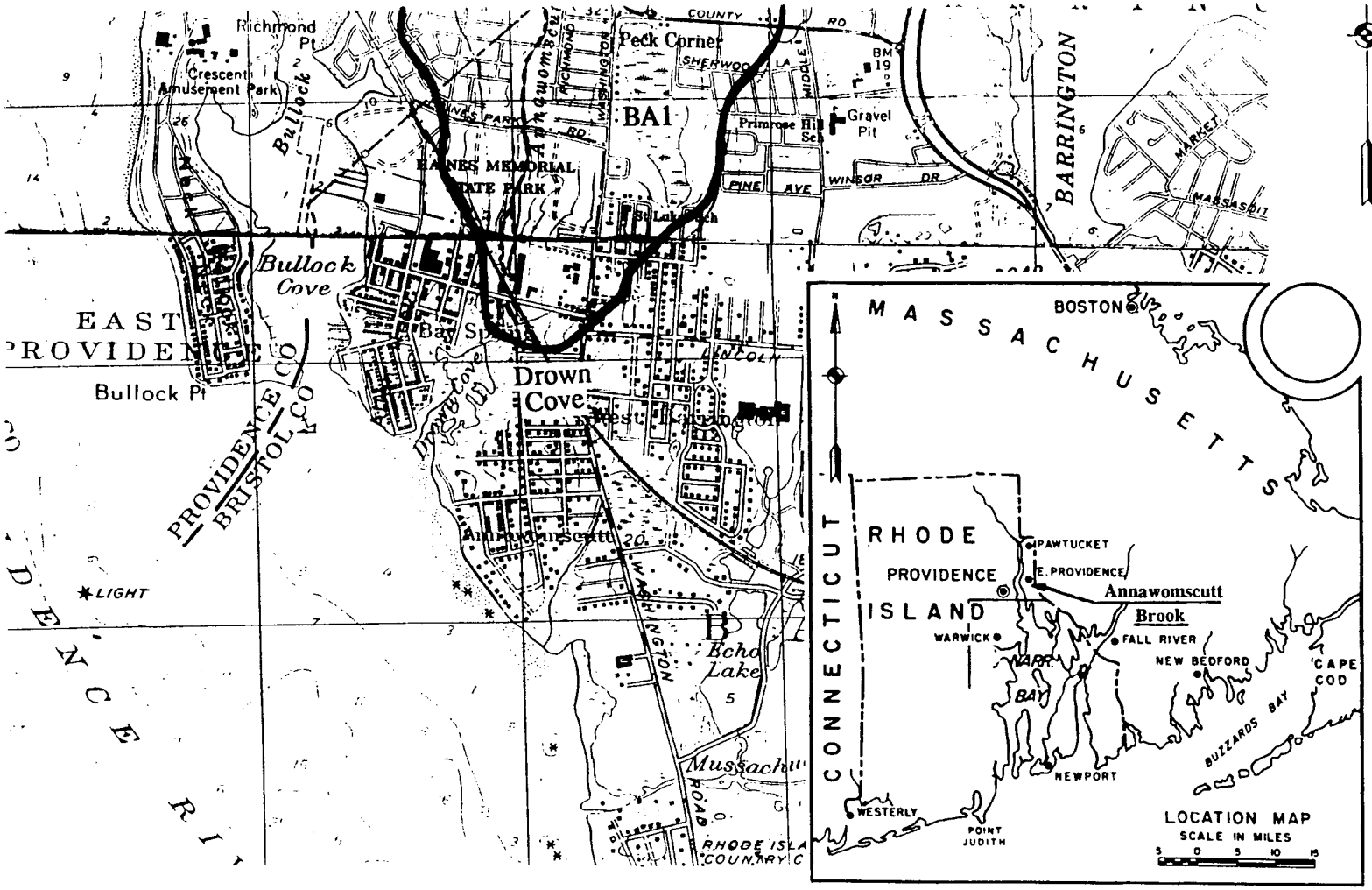
77
BM
7
N


EP1
EP2
EP3
EP4
BA1
Forbes St. Landfill
Kent Corner
Peck Corner
Riverside
Nockum Hill
Bullock Cove
Drown Cove
Annawomscutt
Primrose Hill
Tidal Flat
The Tongue
BARRINGTON
Bullock Pt
EAST PROVIDENCE
PROVIDENCE CO
BRISTOL CO
Radio Towers (WJAR)
Radio Towers (WPRO)
Pumping Sta
Neighborhood Center
Willett Pond
Riverside High Sch
Meadow Crest Sch
Platt Sch
St Brendans Sch
Waddington Sch
Barrington College
Primrose Hill Sch
Lincoln Sch
Gravel Pit
Crescent Amusement Park
Richmond Pt
BAINES MEMORIAL STATE PARK
Bay Spring
West Barrington
Echo
N
MASSACHUSETTS
BOSTON
RHODE ISLAND
PROVIDENCE
PAWTUCKET
E. PROVIDENCE
Annawomscutt Brook
WARWICK
FALL RIVER
NEW BEDFORD



Scale 1:25,000

Southeast Area Drainage District
Annawomscutt Brook

East Providence, Rhode Island

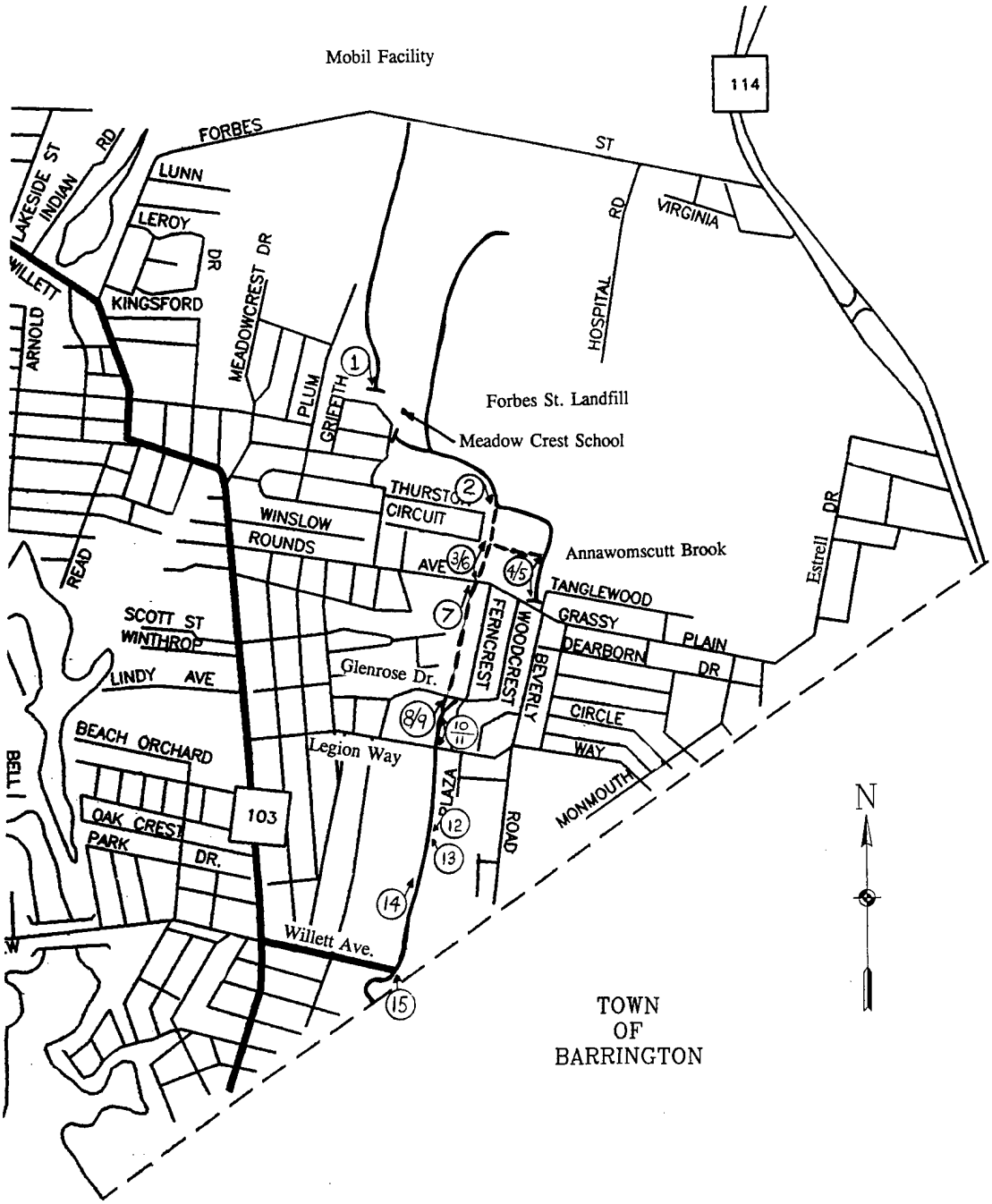
Southeast Area Drainage District

Annawomscutt Brook Watershed

Annawomscutt Brook

US Army Corps of Engineers
New England Division

Plate 1 - Study Area



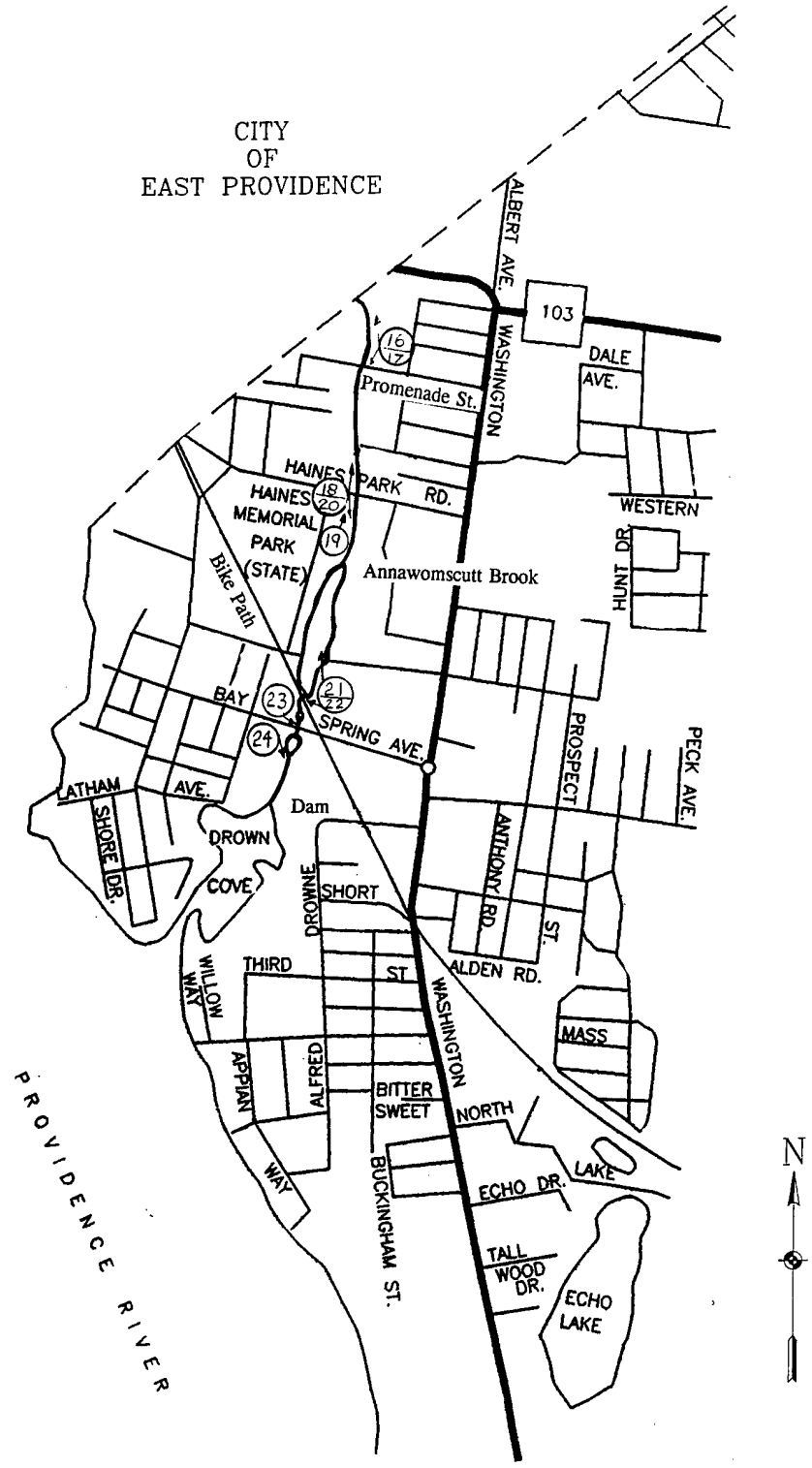
Southeast Area Drainage District
Annawomscutt Brook

East Providence, Rhode Island

(8) – Photo Location

Photo Location Map - East Providence

US Army Corps of Engineers
New England Division



Southeast Area Drainage District
Annawomscutt Brook

East Providence, Rhode Island

16 – Photo Location

Photo Location Map - Barrington

US Army Corps of Engineers
New England Division

Photo 1 - Griffith Drive access road, 24" diameter pipe.

Photo 2 - Normal flow path turns to east in vicinity of Thurston Street. Secondary channel continues to the south.

Southeast Area Drainage District
Annawomscutt Brook

East Providence, Rhode Island

New England Division
U.S. Army Corps of Engineers

Photo 3 - Upstream of Rounds Ave. No flow in secondary channel.
Looking north from Rounds Avenue.

Photo 4 - Upstream of Rounds Ave. & Tanglewood Drive.
No flow in secondary channel, looking northeast.

Southeast Area Drainage District
Annawomscutt Brook

East Providence, Rhode Island

New England Division
U.S. Army Corps of Engineers

Photo 5 - Normal flow path enters 48" diameter pipe @ Tanglewood Drive and Rounds Avenue.

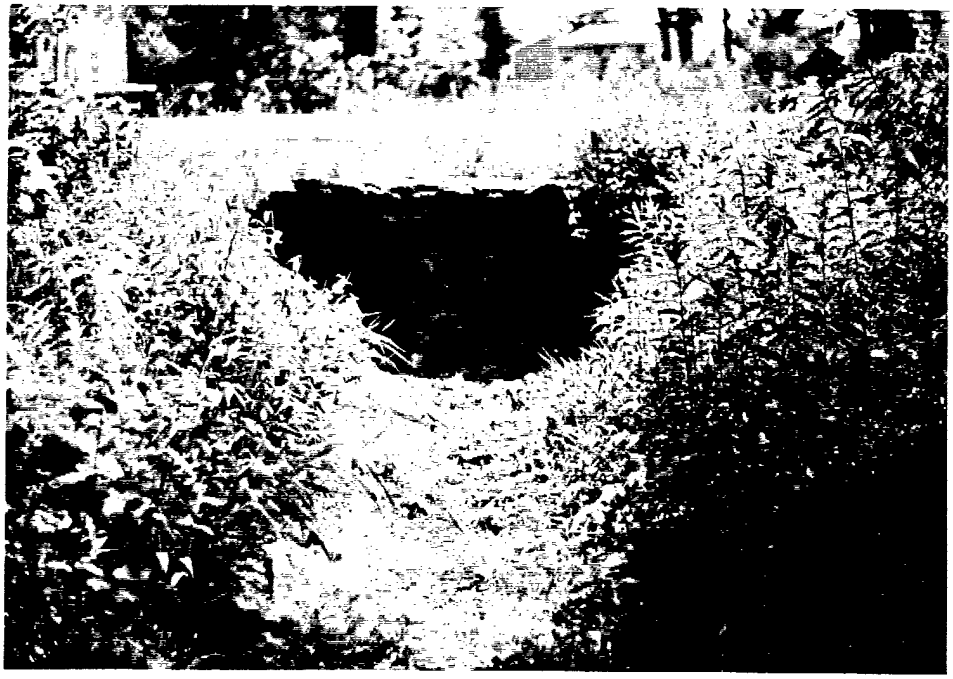


Photo 6 - Upstream end of culverts at Rounds Avenue.

Southeast Area Drainage District
Annawomscutt Brook

East Providence, Rhode Island

New England Division
U.S. Army Corps of Engineers

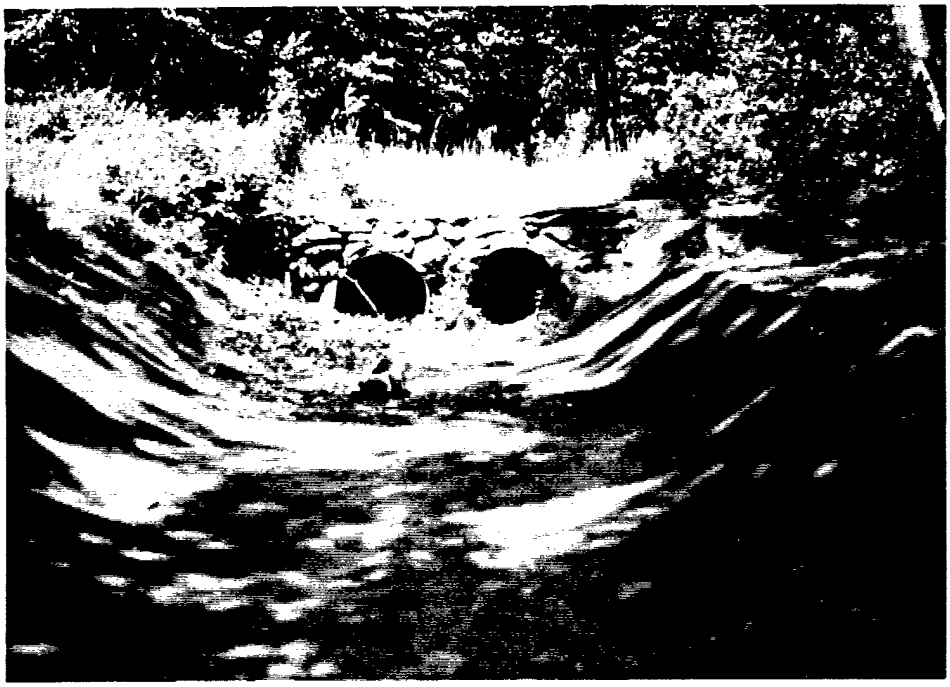


Photo 7 - Downstream end of culverts at Rounds Avenue. Note channel is paved.

Photo 8 - Downstream of Glenrose Drive. 30" diameter pipe.

Southeast Area Drainage District
Annawomscutt Brook
East Providence, Rhode Island

New England Division
U.S. Army Corps of Engineers

Photo 9 - Downstream of Glenrose Drive. Note two 36" diameter pipes is outfall for drainage network conveying normal flow path. Secondary channel enters at the left.

Photo 10 - Typical channel looking upstream (north) from Legion Way.

Southeast Area Drainage District
Annawomscutt Brook

East Providence, Rhode Island

New England Division
U.S. Army Corps of Engineers

Photo 11 - Upstream @ Legion Way looking south.

Photo 12 - Upstream end of north access road at plaza parking lot.

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Annawomscutt Brook
East Providence, Rhode Island

New England Division
U.S. Army Corps
of Engineers

Photo 13 - Downstream end of north access road at plaza parking lot.

Photo 14 - Downstream end of south access road at plaza parking lot.

Photo 15 - Downstream @ Willett Avenue. Note headwall on right for 3.5' diameter drainage pipe.

Photo 16 - Typical brook configuration. Looking upstream from Promenade Street.

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Annawomscutt Brook

East Providence, Rhode Island

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Photo 17 - Upstream end @ Promenade Street.

Photo 18 - Typical channel configuration. Looking upstream from Haines Park Road.

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Annawomscutt Brook

East Providence, Rhode Island

New England Division
U.S. Army Corps of Engineers

Photo 19 - Downstream end of Haines Park Road culverts.

Photo 20 - Typical channel configuration. Looking downstream from Haines Park Road.

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Annawomscutt Brook

East Providence, Rhode Island

New England Division
U.S. Army Corps of Engineers

Photo 21 - Looking upstream north of bike path.

Photo 22 - Upstream end of stone culvert under bike path.

Photo 23 - Upstream at 60" diameter culvert under Bay Spring Avenue.

Photo 24 - Dam and weir structure at Drown Cove.

Southeast Area Drainage District
Annawomscutt Brook

East Providence, Rhode Island

New England Division
U.S. Army Corps of Engineers

Appendix A

Hydrologic & Hydraulic Analysis

SOUTHEAST AREA DRAINAGE DISTRICT
FLOOD PLAIN MANAGEMENT STUDY
EAST PROVIDENCE, RHODE ISLAND

HYDROLOGIC AND HYDRAULIC ANALYSIS

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SOUTHEAST AREA DRAINAGE DISTRICT
FLOOD PLAIN MANAGEMENT STUDY
EAST PROVIDENCE, RHODE ISLAND

HYDROLOGIC AND HYDRAULIC ANALYSIS

1. PURPOSE

The Corps of Engineers was requested by the city of East Providence, Rhode Island to conduct an investigation of flooding problems due to surface water levels in the city's Southeast Area Drainage District. This surface water drainage study presents results of hydrologic and hydraulic analyses of the Annawomscutt Brook in East Providence and Barrington, Rhode Island. The study was conducted under the Corps of Engineers Flood Plain Management Services (FPMS) Program. The FPMS program is authorized under Section 206 of the Flood Control Act of 1960 (PL-86-645).

Although this analysis considers the entire drainage area of the Annawomscutt Brook, the focus of effort is on East Providence, Rhode Island, the local sponsor. This report analyzes several sizes of storm events routed through the brook with and without channel improvements. The improvements include: cleaning the channel, resizing culverts, and channel improvements proposed by Camp Dresser and McKee, Incorporated (CDM) in June 1981.

2. WATERSHED DESCRIPTION

a. General. The Annawomscutt Brook has a total drainage area of about 1.94 square miles at the outlet to Drown Cove (see plate 1). Due to the extremely small size of the brook and the corresponding watershed, there is no recorded hydrologic information pertaining to Annawomscutt Brook. The brook forms south of Forbes Street and east of Riverside Junior High School in East Providence. The brook continues southward, and crosses the county boundary south of Willett Avenue, into the town of Barrington in Bristol County.

The watershed for the Annawomscutt Brook was divided into five subareas for the purpose of this analysis (see plate 1). The subarea delineation differs slightly from CDM's analysis and includes a subarea, BA1, in the town of Barrington.

b. Watershed Subarea EP1. Subarea EP1 contributes runoff from the Mobil Oil Company property north of Forbes Street. There is a large woody and swampy area between the

Mobil tank farm and the 30-inch diameter reinforced concrete culvert, which conveys runoff under Forbes Street and into subarea EP2. This culvert is at the upstream end of one of two main tributaries to Annawomscutt Brook.

c. Watershed Subarea EP2. This subarea is just south of subarea EP1. About 12 acres of the Forbes Street Landfill are incorporated in this 139-acre subarea. The southwestern portion contains about 87 acres of residential land, while the remainder of the subarea is woody with swampy pockets. The tributary from EP1 eventually discharges into a 24-inch reinforced concrete pipe (RCP) located north of Griffith Drive (see photo 1 of main report). The pipe network travels along the west side of Meadowcrest Elementary School and spills into a natural channel, which joins Annawomscutt Brook.

d. Watershed Subarea EP3. The Forbes Street Landfill occupies 49 acres of this 317-acre subarea. Approximately 32 percent of the subarea is residential, and about 52 percent is woody and swampy with patches of dryer open area. A significant portion of the watershed's runoff is stored in a natural depression in topography in the eastern section of the subarea, between the landfill and Estrell Drive.

In the southwest corner of the subarea, the Annawomscutt Brook makes a natural 90 degree bend to the east (see photo 2 of main report). The city of East Providence has excavated a channel to force the brook to continue to flow south towards Rounds Avenue (see photo 3 of main report). During low flows, however, the brook remains on its natural path. The natural channel runs east for approximately 650 feet, and then heads south again. About 450 feet downstream, there is another 90 degree bend to the west (see photo 4 of main report), which reconnects with the excavated reach, but at low flows the brook naturally continues south to a 48-inch diameter RCP (see photo 5 of main report). Flow continues into a drainage system beneath Rounds Avenue and into watershed subarea EP4.

During a reconnaissance trip in April 1995, there was no flow in the secondary channels, but there was storage within the rectangle formed by the channels. The dry channels may carry flow during storm events. At Rounds Avenue, the north-south secondary channel feeds two 30-inch diameter corrugated metal culverts (see photo 6 of main report), located about
750 feet to the west of the 48-inch diameter RCP.

e. Watershed Subarea EP4. Subarea EP4 encompasses 282 acres. Ninety percent of this subarea is residential and commercial. The two 30-inch diameter culverts crossing

under Rounds Avenue from watershed subarea EP3 discharge into an asphalt-lined channel (see photo 7 of main report). The asphalt channel continues approximately 900 feet to a point just south of Robin Hood Drive, where it once again becomes a natural channel. Approximately 300 feet further downstream at Glenrose Drive, the channel reconvenes with the effluent from an underground pipe system (see photo 9 of main report). The channel was dry from Rounds Avenue to Glenrose Drive during reconnaissance visits in late April and early May 1995.

The pipe system begins in watershed subarea EP3 at the 48-inch culvert opening. This culvert feeds two 36-inch pipes, which cross Rounds Avenue and turn west down Rounds Avenue to the right-of-way on the east boundary of the Covenant Congregational Church property. From here, the two 36-inch pipes enter a 48-inch pipe, which flows south along the church boundary to Glenrose Drive. At Glenrose, the 48-inch pipe feeds two 36-inch culverts, which travel under Glenrose and discharge back into the natural channel of Annawomscutt Brook.

From field observations and for purpose of analysis, it was assumed that for 2-year frequency storm events and smaller, the majority of flow traveled through the pipe network. Larger events were split between the pipe network and channel. Based on the assumption that the water surface elevation at the upstream end of the two 30-inch diameter culverts is the same as the water surface elevation at the upstream end of the pipe network, and utilizing the energy equation and losses within the pipes, it was estimated that no more than 50 cfs flow through the pipes.

Approximately 600 feet further downstream, the brook flows through a 42-inch diameter culvert at Legion Way (see photos 10 and 11 of main report). The brook continues about another 900 feet downstream, and crosses through a large strip mall parking area. Two access roads cross over the brook. Beneath the northern access road are twin 72-inch corrugated metal culverts (see photos 12 and 13 of main report), while two 36-inch corrugated metal culverts pass under the south access road (see photo 14 of main report). At the downstream end of the parking area, the brook flows through a 5- by 12-foot opening under Willett Avenue (see photo 15 of main report) and into the town of Barrington, Rhode Island.

f. Watershed Subarea BA1. Forty-two percent of this 403-acre subarea is residential. Annawomscutt Brook flows through culverts at Promenade Street and Haines Park Road (see photos 16 through 20 of main report). A large storage

area, with an estimated capacity of approximately 170 acre-feet, is located between Haines Park Road and a bike path (see photo 21 of main report). The flow out of the storage area, which consists of a swampy area and a pond, is restricted by a 4- by 2-foot stone masonry culvert (see photo 22 of main report). The culvert passes the brook under the bike path, which was once a Conrail line. The flow then enters another small storage area, passes through an estimated 5-foot diameter culvert (see photo 23 of main report), and travels down a wide channel to a small dam (see photo 24 of main report), where it spills over into Drown Cove.

3. CLIMATOLOGY

a. Precipitation. Precipitation has been recorded since 1905 at Providence. Average annual precipitation at Providence is about 42.1 inches, distributed quite uniformly throughout the year, and averaging about 3.5 inches per month. Average and extreme monthly precipitation values are shown in table 1.

TABLE 1

MONTHLY PRECIPITATION IN INCHES
PROVIDENCE, RHODE ISLAND
(Gage Elevation 51 Feet NGVD, 89 Years of Record)

Month	Mean	Maximum	Minimum
January	3.74	11.66	0.50
February	3.27	7.20	0.39
March	3.83	8.84	0.56
April	3.74	12.74	1.48
May	3.28	8.38	0.71
June	3.04	11.08	0.39
July	3.18	8.08	1.00
August	3.72	11.12	0.71
September	2.33	7.92	0.77
October	3.19	11.89	1.53
November	3.87	11.01	0.81
December	3.87	10.75	0.58
Annual	**42.08**	**67.52**	**25.44**

b. Rainfall Frequencies. Short duration, intense rainfall often accompanies fast moving frontal systems, thunderstorms, and coastal storms. Peak storm rainfall frequency-duration data, as reported in U.S. Weather Bureau Technical Paper 40 (reference h), are summarized in table 2.

TABLE 2

RAINFALL FREQUENCY DURATION
USWB TECHNICAL PAPER 40
EAST PROVIDENCE, RHODE ISLAND
(Inches)

Annual Frequency		Duration in Hours				
Percent	Year	1	2	6	12	24
50	2	1.2	1.6	2.3	2.7	3.3
20	5	1.6	2.1	2.9	3.5	4.2
10	10	2.0	2.5	3.5	4.1	4.9
4	25	2.2	2.9	4.0	4.9	5.5
2	50	2.6	3.2	4.3	5.2	6.2

4. STUDY PROCEDURE

a. General. The following sections describe the approach used to analyze the flooding problems along Annawomscutt Brook. The U.S. Army Corps of Engineers Hydrologic Engineering Center's HEC-1, "Flood Hydrograph Package," was utilized to develop flood hydrographs. Peak flows from the hydrographs were subsequently applied to HEC-2, "Water Surface Profiles."

This report only considers effects of surface water on the flood plain of Annawomscutt Brook. Effects of groundwater, which are not considered a significant component of flooding, are a separate issue and were not addressed. In addition, improvements proposed by CDM in June 1981, which were intended to lower the groundwater table, were not analyzed.

b. Rainfall Runoff Hydrograph Development. Due to the lack of hydrologic information pertaining to Annawomscutt Brook, peak flow rates in the brook had to be estimated. Rainfall data were input into HEC-1. To obtain storm hydrographs at the downstream end of each watershed sub-area, the U.S. Department of Agriculture Natural Resources Conservation Service (NRCS) Runoff Curve Number Method

within HEC-1 was utilized. Drainage areas, curve numbers, and lag times for the SCS Method were determined, based on U.S. Geological Survey (USGS) quadrangles, SCS soil survey of Rhode Island (reference g), and information within CDM's Report on Drainage Improvements (reference a).

Muskingum-Cunge routing was employed to model the attenuation of upstream subarea hydrographs as they passed through subsequent subareas. Although many gradually sloped, swampy pockets of land exist within the watershed, no attempt was made to model storage during this portion of the analysis. However, only one storage area, which is considered in later portions of this analysis, appears to have significant impact on peak flows within the channel.

Without hydrologic data for the brook, other information had to be obtained to attempt to verify the peak flows obtained in the HEC-1 model. One method of model calibration involves comparison with nearby gaged rivers for a series of known storm events. Comparisons were attempted utilizing both the Moshassuck River gage in Providence, Rhode Island and the Runnins River gage in Seekonk, Massachusetts. However, differences in the characteristics of these watersheds did not offer suitable correlation.

The USGS has published several reports with regression equations describing different flow characteristics based on physical watershed features (reference i). Some drawbacks attributed to these empirical equations are the high standard error of regression estimates and the short period of record (6-years for Rhode Island) used to develop the equations. Using a 50-year, 24-hour event, as reported in U.S. Weather Bureau Technical Paper 40 (reference h), the HEC-1 model was adjusted with consideration of the results of the regression equations developed for Rhode Island. In addition, the peak flow at Willett Avenue for a 50-year storm, as determined by CDM's 1981 report, was also considered for further calibration.

Rainfall for the 2, 5, 10, 25, and 50-year, 24-hour events, as shown in table 2, was applied to the watershed model. Runoff from each subbasin was routed downstream to the brook outlet at Drown Cove using Muskingum-Cunge routing. The results of this analysis are presented in table 3, which lists index stations and peak runoff rates for each different frequency event analyzed.

c. Water Surface Profile Development. Once a number of synthetic storm hydrographs were developed, and peak discharges established for points along the brook, water surface profiles were computed utilizing HEC-2. For subcritical flow regimes in HEC-2, profile computations begin with assumed flow rates and starting water surface elevations at a downstream cross section, and proceed upstream. Brook cross sections were obtained by field survey, and the Manning's "n" values adopted are shown in table 4. Starting water surface elevations were obtained from a rating curve developed for the dam at the downstream end of the reach (see plate 2). Profiles were generated for flows associated with the five synthetic storms developed with the HEC-1 analysis. Five additional flow rates were developed by interpolating or extrapolating peak flows from the synthetic storm peak flows, and were analyzed in the HEC-2 model.

TABLE 3

ESTIMATED PEAK FLOWS
AT DOWNSTREAM LOCATIONS OF SUBAREAS

Location	Total Drainage Area ($mi.^2$)	Computed Peak Flows in CFS 2-yr	5-yr	10-yr	25-yr	50-yr
Forbes St.	0.15	12	22	33	43	53
Thurston St.	0.37	21	40	59	78	97
Rounds Ave.	0.87	49	93	140	191	240
Willett Ave.	1.31	88	159	233	312	387
Drown Cove	1.94	99	190	282	385	483
Drown Cove (w/ storage)	1.94	42	53	67	82	95

TABLE 4

MANNING'S "n" VALUES UTILIZED IN HEC-2 ANALYSES

Type of Channel or Surface	"n"
Existing Brook Channel	0.030 - 0.040
Existing Overbanks	0.025 - 0.090
Asphalt Channel	0.013
Clean Channel	0.028
Improved Channel	0.020
Corrugated Metal Pipe	0.016 - 0.026
Bike Path Culvert	0.040
New Concrete Box Culverts	0.014

The ten profiles were considered adequate to estimate the amount of storage between the bike path culvert and Haines Park Road in the town of Barrington. Utilizing methods described in the Hydrologic Engineering Center's Training Document 30 (reference d), HEC-1 was used in conjunction with the HEC-2 model to simulate modified Puls routing through the storage reach. Peak flows from the storage reach outflow hydrograph were then adopted as the Drown Cove peak flows, as shown in table 3, for the final HEC-2 model. It should be noted that attenuation in the storage area accounts for a time to peak 2 to 4 times greater than when storage is not considered, and, as shown in table 3, peak discharges downstream of the storage area are significantly reduced. Plate 3 is an example of hydrographs developed for a 25-year storm. It includes hydrographs at Rounds and Willett Avenues, and the inflow and outflow hydrograph at the Barrington storage area. This hydrograph analysis shows the considerable attenuation and storage effects through the Barrington storage reach.

In an attempt to validate the entire model, three historical storm events were run through the steps described in paragraphs 4b and 4c. The water surface profiles developed for the three events, which were in the order of the synthetic 2-year storm, were compared to flooding logs kept by the city of East Providence. No deviation was exhibited between the modeled results, as exhibited in plate 6, and actual historic records.

5. ANALYSIS RESULTS

a. General. Water surface profiles were developed for the existing channel of the Annawomscutt Brook. A number of adjustments, such as cleaning the channel and increasing culvert sizes were entered into the model. In addition, channel improvements and rerouting of surface waters, as proposed by CDM were analyzed. Manning's "n" values utilized in the analyses are listed in table 4.

b. Existing Conditions. Water surface profiles for the existing conditions of Annawomscutt Brook were estimated using the methods described in paragraph 4. Plate 4 exhibits profiles for the 2, 5, 10, and 25-year synthetic storms. Table 5 lists elevations of the channel, structures, and top of road crossings along the reach, and table 6 lists water surface elevations at the same locations as shown on plate 4. Invert and top of road elevations were obtained by field surveys and USGS quadrangles.

The most upstream cross section on the profiles represents a point just north of the intersection between the easterly bend and the excavated channel. Continuing the HEC-2 model further upstream would not impart any useful information since the brook travels through woodlands and the Forbes Street Landfill.

The profiles demonstrate that most culverts along Annawomscutt Brook are undersized. The most significant example is the bike path culvert. The limited flow capacity of the 4-foot vertical by 2-foot horizontal culvert appears to govern the water surface elevation upstream through the storage area, Haines Park, and onto Promenade Street. Although the city of East Providence has design criteria based on a 25-year frequency storm, culverts at Haines Park Road, Promenade Street, the south access road at the Almac's parking area, Legion Way, Glenrose Drive, and Rounds Avenue have capacities less than the peak runoff from a 2-year event.

The 2-year storm profile shown on plate 4 ends at the downstream side of Glenrose Drive. All flow from this size storm or smaller is assumed to flow through the pipe network as described in paragraph 2e. For larger storms, where flow is split between the channel and the pipe network, the profile upstream of Glenrose Drive, shown on plate 4, represents flow in the channel only.

TABLE 5

ELEVATIONS OF EXISTING STRUCTURES
ALONG ANNAWOMSCUTT BROOK

Structure Location	Channel Invert Elev. (ft.)*	Culvert Invert Elev. (ft.)*	Top of Road Elev. (ft.)*
Drown Cove Dam	0.00	N/A	N/A
Bay Spring Ave.			
d/s end	1.29	1.29	14.90
u/s end	1.46	1.46	14.90
Bike Path			
d/s end	3.40	3.40	20.00
u/s end	3.55	3.55	20.00
Haines Park Road			
d/s end	7.13	7.13	10.83
u/s end	7.25	7.25	10.83
Promenade Street			
d/s end	9.07	8.94	15.94
u/s end	9.21	8.95	15.94
Willett Avenue			
d/s end	9.35	8.79	18.97
u/s end	9.67	8.82	18.97
S. Almac's Access Rd			
d/s end	10.42	10.07	14.78
u/s end	10.70	10.07	14.78
N. Almac's Access Rd			
d/s end	11.23	9.86	16.69
u/s end	11.30	10.64	16.69
Legion Way			
d/s end	12.31	12.31	18.30
u/s end	12.05	12.48	18.30
Glenrose Avenue			
d/s end	15.12	15.24	19.67
u/s end	15.45	16.02	19.67
Rounds Avenue			
west d/s end (channel)	18.56	18.75	23.15
west u/s end (channel)	18.80	19.02	23.15
east - u/s pipe system	19.33	19.33	24.35

Note: Invert and top of road elevations were approximated by field surveys and USGS Quadrangles.

* Elevations referenced to East Providence datum. East Providence datum is 2.35 feet above NGVD.

TABLE 6

ESTIMATED WATER SURFACE PROFILE ELEVATIONS
ALONG EXISTING CHANNEL

Structure Location	2-Year Storm (ft.)*	5-Year Storm (ft.)*	10-Year Storm (ft.)*	25-Year Storm (ft.)*
Drown Cove Dam	6.99	7.17	7.38	7.59
Bay Spring Ave.				
d/s end	6.99	7.17	7.38	7.59
u/s end	7.16	7.45	7.82	8.25
Bike Path				
d/s end	7.16	7.45	7.82	8.25
u/s end	8.86	10.07	12.89	15.85
Haines Park Road				
d/s end	9.03	10.07	12.89	15.85
u/s end	10.65	10.99	12.89	15.85
Promenade Street				
d/s end	11.23	11.80	12.89	15.86
u/s end	13.64	14.25	14.68	15.86
Willett Avenue				
d/s end	13.77	14.44	14.93	15.98
u/s end	13.78	14.55	15.23	16.61
S. Almac's Access Rd				
d/s end	14.16	15.06	15.73	16.80
u/s end	15.10	15.79	16.14	16.80
N. Almac's Access Rd				
d/s end	15.17	15.88	16.24	16.84
u/s end	15.17	16.09	16.68	17.22
Legion Way				
d/s end	16.26	17.34	18.08	18.62
u/s end	17.88	18.21	18.40	18.63
Glenrose Avenue				
d/s end	18.17	18.92	19.28	19.49
u/s end	N/A	19.89	20.06	20.18
Rounds Avenue				
west d/s end (channel)	N/A	19.89	20.32	20.80
west u/s end (channel)	N/A	21.18	21.40	21.59
east - u/s pipe syst.**	20.52	22.30	22.56	22.78

* Elevations referenced to East Providence datum. East Providence datum is 2.35 feet above NGVD.

** Pipe network not shown on profiles.

c. Alternative Proposals

(1) Clean Channel. Reconnaissance visits to Annawomscutt Brook revealed that the channel is not well maintained in some areas. In particular, the embankments in Almac's parking area and the west bank along the Waddington School contain an excess of brush, and the channel is not aligned with the culverts. Culverts at Promenade Street, the Almac's parking area, and Legion Way have silt accumulated along their inverts. In addition, officials from East Providence explained that during high runoff events, the Annawomscutt conveys little flow, with substantial water being stored, until debris is removed from culverts downstream in the town of Barrington, which then allows the brook to drain.

The HEC-2 model was set up to represent the existing channel without vegetation along the embankments or silt within the culverts. A Manning's roughness coefficient of 0.028, which represents a dragline-excavated or dredged channel with no vegetation, was used along the channel. The only significant effect of these changes to the model was at the downstream end of the Legion Way culvert, where the water surface elevation dropped approximately 0.7 foot for peak runoffs from 2-year through 25-year storms. Otherwise, water surface elevations changed by no more than one-half foot anywhere along the channel.

It should be noted that the Manning's values chosen to model the existing channel did not significantly differ from the clean channel value in most locations. Although the model does not indicate a significant reduction in water surface elevation, it is logical to assume that freeing the channel and culverts from debris and vegetation would aid in the conveyance of flow. Channel velocities within the East Providence reach of Annawomscutt Brook generally range between 1 to 3 ft/s, which may facilitate sediment deposition, especially at high flow rates. It is suggested that the city initiate a general maintenance program to mitigate continuing problems.

(2) Increase Culvert Sizes. As stated above, the bike path culvert creates significant backwater effects to Promenade Street. A 6-foot diameter corrugated metal culvert and twin 5 by 5-foot box culverts were each inputted into the model at the bike path. Water surface elevations downstream of the bike path increased, since greater flows were released from the storage area. As expected, water surface elevations decreased through the storage area, Haines Park Road, and Promenade Street; however, there was no significant effect upstream in East Providence.

With the twin box culverts at the bike path, backwater effects to Promenade Street were the result of the restriction of the Bay Spring Avenue culvert. Another twin 5- by 5-foot box culvert was placed into the model to replace the Bay Spring Avenue culvert. Again, minimal effects were observed in East Providence.

Moving further upstream, the Promenade Street culvert creates considerable energy loss. Returning the downstream culverts to their actual sizes, the Promenade Street culvert was replaced in the model with twin 5- by 5-foot box culverts. This model had some effect on the water surface elevation up to the north access road at the Almac's parking area for events smaller than the 25-year storm. The 2- and 5-year storm water surface elevations at the south access road were estimated to be one-half foot less than the estimated elevation for existing conditions. This denotes slightly less overtopping of the south access road occurring during storm sizes between the 2- and 5-year events. Further upstream of the parking area, however, there is no impact from enlarging the Promenade Street culvert.

Due to siltation in the channel, the culvert inverts at the north and south access roads in the Almac's parking area are located below the streambed elevation. Also, the twin 36-inch culverts at the south access road are well undersized. The model was run with these two sets of culverts brought up to the streambed elevation. The south culverts were replaced by twin 4- by 4-foot box culverts, and the north culverts were replaced by twin 6 by 6-foot box culverts. Unfortunately, the topography restricts the size of the south culverts, so they must be smaller than the north culverts. Additionally, elevations of the access roads had to be increased by approximately one foot to accommodate the new culverts. Again the results were encouraging for storms equivalent to, or smaller than, the 2-year event, with water surface elevations decreasing by approximately one foot in the channel for a 2-year event. Water surface elevations for events between the 2- and 10-year storms were lower than with the existing culverts by a few inches, and there was no effect on the 25-year event. Water surface elevations at Legion Way were not affected.

(3) Proposed Channel Configuration. In their June 1981 report, CDM recommended a general lowering (i.e., average of 3.5 feet) and reshaping of Annawomscutt Brook between Meadowcrest School and Willett Avenue, and construction of concrete box culverts at Rounds Avenue, Glenrose Drive and Legion Way to increase the hydraulic capacity of the brook. Table 7 displays the proposed channel invert elevations. Lowering the brook also would

accommodate the installation of properly functioning, gravity storm water drainage facilities within the area. The new bottom width would vary between 8 and 10 feet, and the existing invert elevation at Willett Avenue would remain

TABLE 7

CHANNEL INVERT ELEVATIONS PROPOSED BY CDM

Location	Elev. (ft.)*	Location	Elev. (ft.)*
Willett Avenue		Legion Way	
d/s end	9.35	d/s end	12.35
u/s end	10.00	u/s end	12.45
S. Almac's Access Rd		Glenrose Avenue	
d/s end	10.68	d/s end	13.65
u/s end	10.71	u/s end	13.81
N. Almac's Access Rd		Rounds Avenue	
d/s end	10.95	d/s end	16.95
u/s end	11.01	u/s end	17.00

* Elevations referenced to East Providence datum. East Providence datum is 2.35 feet above NGVD.

unchanged. Based on available soil data, a side slope of 2 horizontal to 1 vertical was recommended, noting that detailed soil information to be obtained during final design may indicate wider cuts. The new channel was also to be seeded, and allowed to grow to its natural state.

These proposed channel improvements were inputted into the HEC-2 model. All flow was assumed to travel along the excavated channel north of Rounds Avenue, with only street runoff from the immediate area entering the pipe network between Rounds Avenue and Glenrose Drive.

The most significant effects of the proposed changes were the lowering of water surface elevations at Legion Way and Glenrose Drive by as much as 1.5 feet for the 25-year storm event and nearly 2.5 feet for the 2-year event. The new culverts at these locations prevented overtopping of these roads in the model.

These model changes were upstream of the Almac's parking area reach, so there was no effect on this location. Thus, the culverts at the access roads were inputted as twin 4-foot and twin 6-foot box culverts as described in paragraph 5.c.(2). The resulting water surface elevations

at Glenrose Avenue and Legion Way were lowered by a few inches, but the real effect was observed between the north and south access roads. Here the water surface was lowered by approximately 0.8 foot for the 2-year event and one-half foot for the 5-year storm. For larger storms, however, effects of this modification on the model were minimal.

Table 8 shows the anticipated effects on the water surface profile if CDM's improvements and improvements at the Almac's parking area are performed on the existing channel in East Providence. Plate 5 displays the water surface profile and the improved brook invert. Note that the water surface elevation for the improved channel at the parking area is anticipated to be greater than the water surface elevation in the existing channel for larger events. This is due to raising the access road to accommodate the larger culverts, and, thus, raising the elevation that weir flow can commence.

Changes in the proposed sizes of box culverts at Legion Way, Glenrose Drive, and Rounds Avenue were analyzed. For a 25-year storm event and existing topography, the 5- by 5-foot twin box culverts at Glenrose Drive and Legion Way and the 4- by 4-foot twin box culverts at Rounds Avenue appear to be the optimal sizes.

TABLE 8

ESTIMATED WATER SURFACE ELEVATIONS IN EXISTING CHANNEL VERSUS CHANNEL WITH SUGGESTED IMPROVEMENTS

Structure Location	2-Yr Storm		25-Yr Storm	
	Existing (ft.)*	Improved (ft.)*	Existing (ft.)*	Improved (ft.)*
Willett Avenue				
d/s end	13.77	13.77	15.98	15.98
u/s end	13.78	13.80	16.61	16.62
S. Almac's access rd				
d/s end	14.16	13.85	16.80	16.68
u/s end	15.10	14.11	16.80	16.93
N. Almac's access rd				
d/s end	15.17	14.13	16.84	16.93
u/s end	15.17	14.22	17.22	17.30
Legion Way				
d/s end	16.26	14.48	18.62	17.46
u/s end	17.88	14.85	18.63	18.00
Glenrose Avenue				
d/s end	18.17	15.53	19.49	18.32
u/s end	N/A	15.68	20.18	18.71
Rounds Avenue				
west d/s end	N/A	18.23	20.80	19.36
west u/s end	N/A	18.75	21.59	21.39

* Elevations referenced to East Providence datum. East Providence datum is 2.35 feet above NGVD.

(4) Diversion of Watershed Area EP1. Another alternative suggested by CDM, and analyzed in this report, involves diverting stormwater runoff originating from the watershed subarea north of Forbes Street out of the Annawomscutt Brook watershed and into Willett Pond to the southwest. Rainfall runoff hydrographs were developed for the four remaining watershed subareas in the manner described in paragraph 4b. As shown in table 9, runoff from subarea EP1 does not appear to contribute significantly to peak flow at any point along the Annawomscutt for any size storm.

d. Conclusions. Annawomscutt Brook is a gradually sloped, shallow stream which travels through low lying areas with a high groundwater table. In addition, many flow structures along the brook are undersized and further increase the possibility of overtopping channel banks and

TABLE 9

ESTIMATED PEAK FLOW RATES ALONG EXISTING CHANNEL
WITH AND WITHOUT RUNOFF FROM SUBAREA EP1

Storm	Rounds Avenue		Willett Avenue		Drown Cove	
Freq. (yr)	w/ EP1 (cfs)	w/o EP1 (cfs)	w/ EP1 (cfs)	w/o EP1 (cfs)	w/ EP1 (cfs)	w/o EP1 (cfs)
2	49	49	88	88	99	98
5	93	91	159	158	190	187
10	140	131	233	225	282	273
25	191	174	312	295	385	367
50	240	215	387	363	483	458

roads. Since the effects of groundwater are outside the scope of this study, the previous alternatives focused on the reduction of overtopping of roads crossing the brook.

The most hydraulically effective of the analyzed alternatives appears to be the channel improvements proposed by CDM in conjunction with replacing the culverts at the Almac's parking area. Excavating the channel, however, may slightly increase low flow rates if the channel invert is at a lower elevation than the water table. For severe storm events, the improvements modeled do not exhibit marked improvement in reducing overtopping of the channel banks at the Almac's parking area as well as from Willett Avenue through Haines Park Road.

Regardless of the improvements adopted for the Annawomscutt Brook, the city of East Providence should consider cleaning the brook channel and implementing a routine maintenance program. This will improve conveyance of small storms as well as the aesthetic quality of the brook.

6. REFERENCES

a. Camp, Dresser, and McKee, Incorporated, "City of East Providence, Rhode Island, Southeast Area Drainage District, Report on Drainage Improvements," Boston, Massachusetts, June 1981.

b. U.S. Army Corps of Engineers, Hydrologic Engineering Center, "HEC-1 Flood Hydrograph Package," User's Manual, September 1990.

c. U.S. Army Corps of Engineers, Hydrologic Engineering Center, "HEC-2 Water Surface Profiles," User's Manual, September 1990.

d. U.S. Army Corps of Engineers, Hydrologic Engineering Center, "River Routing with HEC-1 and HEC-2," Training Document Number 30, September 1990.

e. U.S. Army Corps of Engineers, New England Division, "Runnins River Watershed Stormwater Management Study," December 1994.

f. U.S. Department of Agriculture, Soil Conservation Service, Technical Release Number 55, "Urban Hydrology for Small Watersheds," June 1986.

g. U.S. Department of Agriculture, Soil Conservation Service, "Soil Survey of Rhode Island," 1991.

h. U.S. Department of Commerce, Weather Bureau, Technical Paper 40, "Rainfall Atlas of the United States for Durations of 30 Minutes to 24 Hours and Return Periods from 1 to 100 Years," 1961.

i. U.S. Department of the Interior, Geological Survey, Open-File Report 76-883, "Flood Magnitude and Frequency of Small Rhode Island Streams," Boston, Massachusetts, 1976.

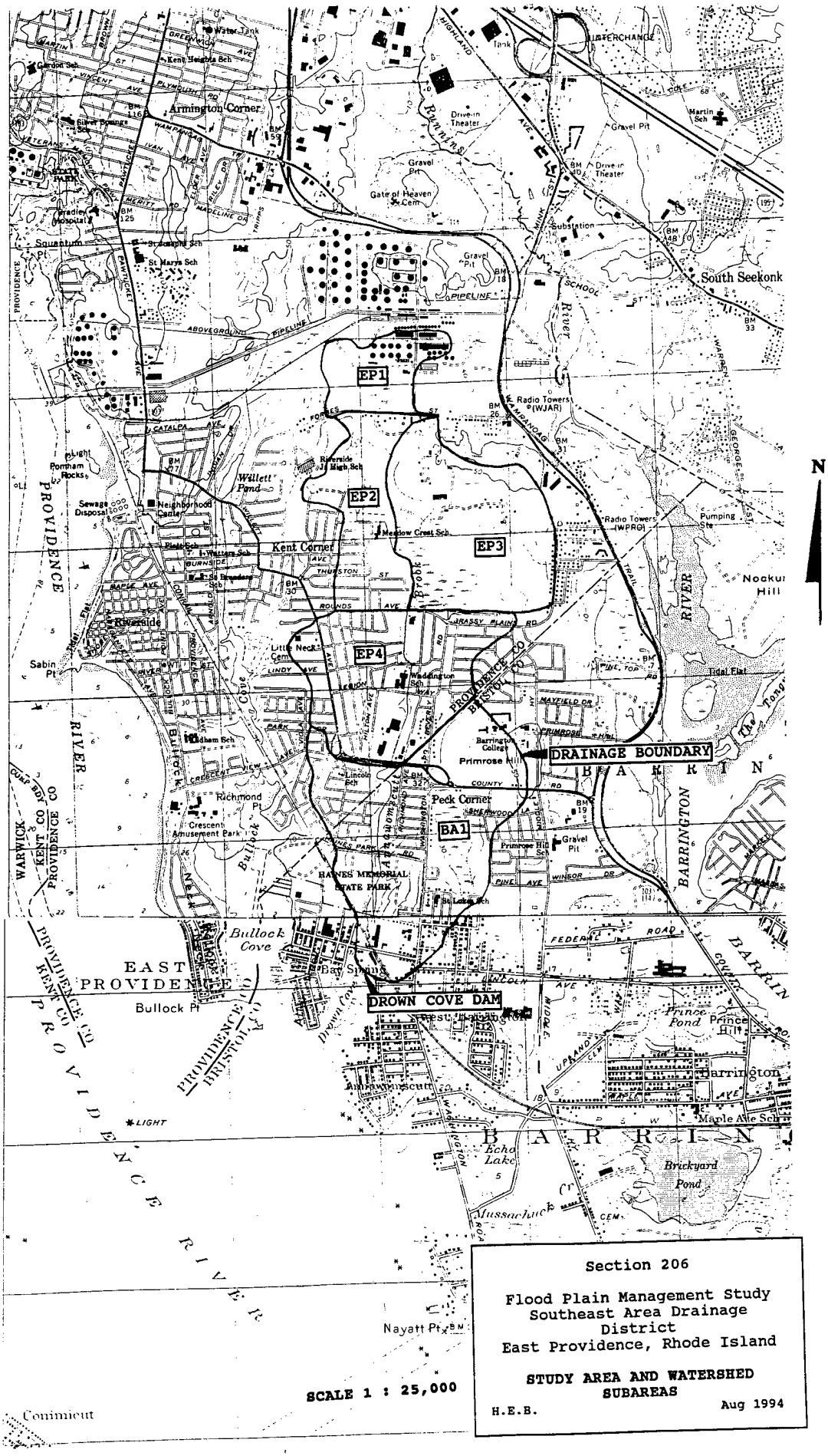

EP1
EP2
EP3
EP4
BA1
DRAINAGE BOUNDARY
DROWN COVE DAM
N
SCALE 1 : 25,000
Armington Corner
Kent Corner
Peck Corner
Bullock Cove
Willett Pond
Prince Pond
Brickyard Pond
Echo Lake
Nayatt Pt
Bullock Pt
Sabin Pt
Riverside
Pomham Rocks
Tidal Flat
Nockum Hill
South Seekonk
EAST PROVIDENCE
BARRINGTON
PROVIDENCE RIVER
Section 206
Flood Plain Management Study
Southeast Area Drainage District
East Providence, Rhode Island
STUDY AREA AND WATERSHED SUBAREAS
H.E.B.
Aug 1994

PLATE 1

Drown Cove Dam Rating Curve

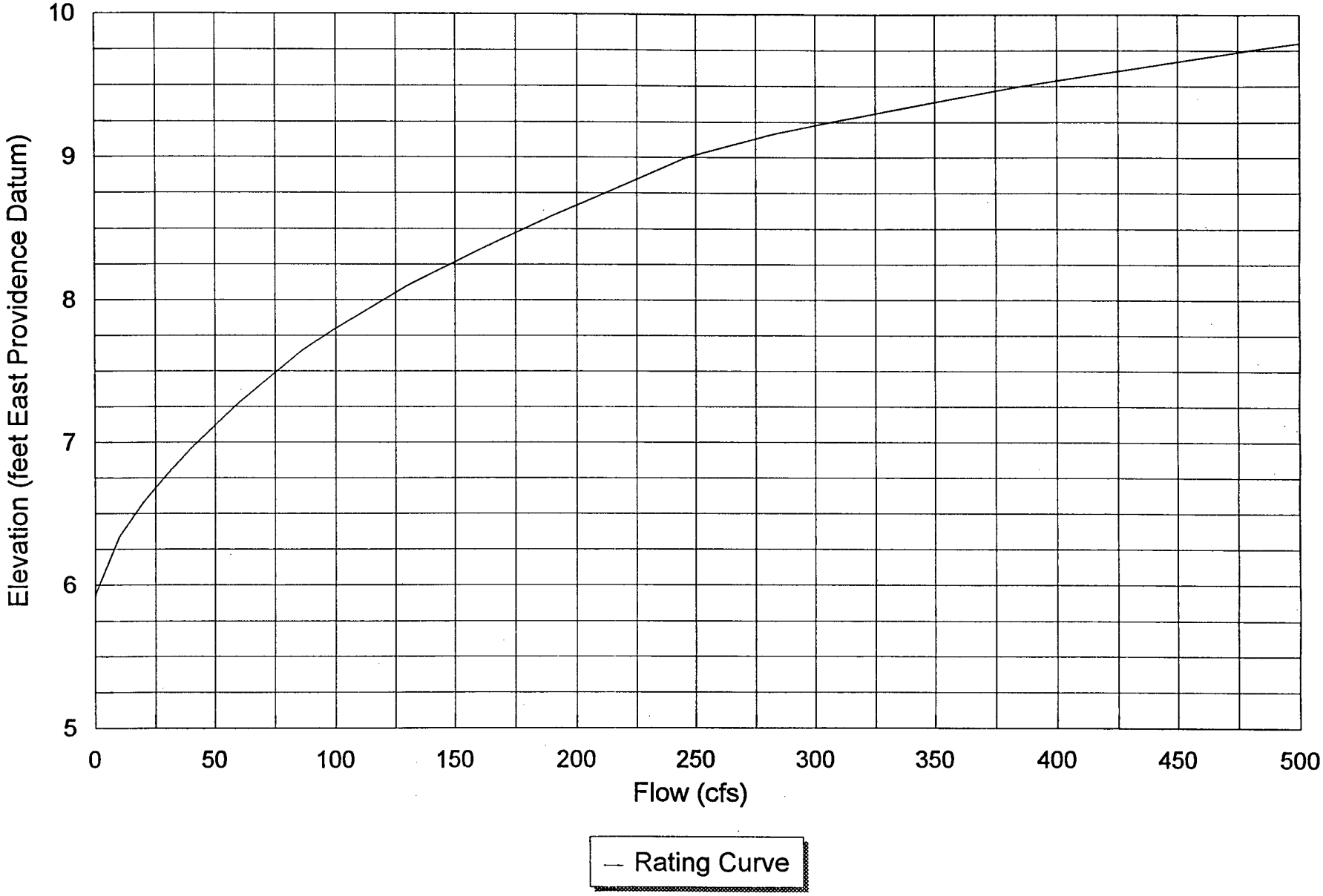
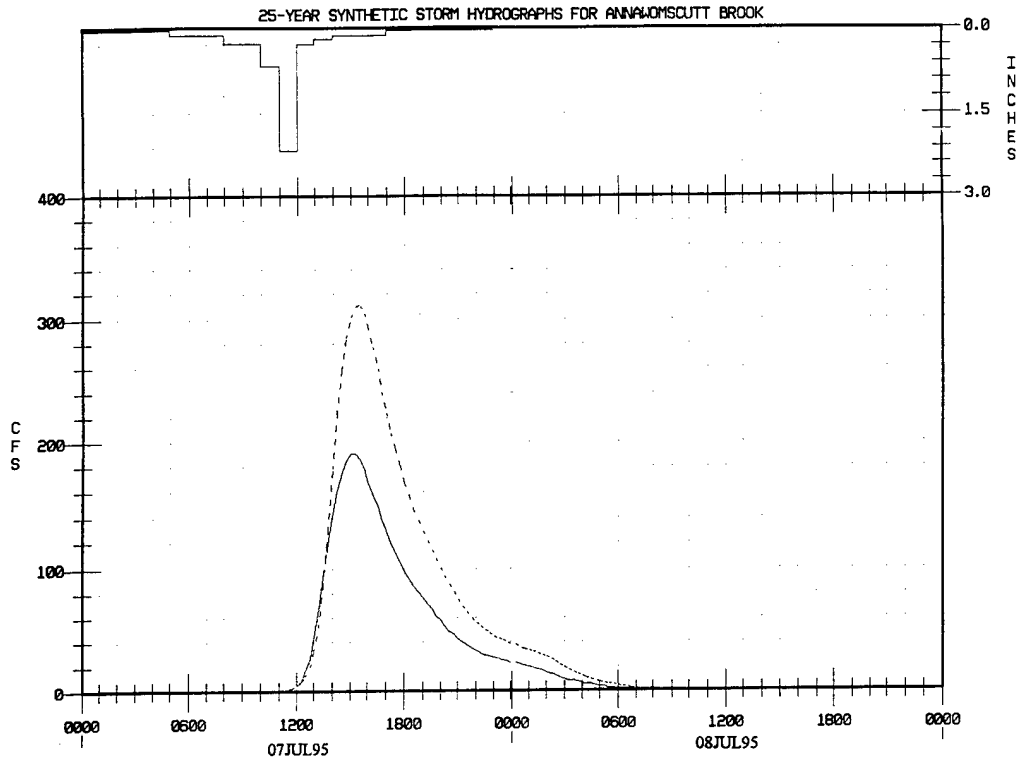


PLATE 2


25-YEAR SYNTHETIC STORM HYDROGRAPHS FOR ANNAWOMSCUTT BROOK
0.0
1.5
3.0
INCHES
400
300
200
100
0
CFS
0000
0600
1200
1800
0000
0600
1200
1800
0000
07JUL95
08JUL95
rainfall hyetograph
Rounds Ave. hydrograph
(D.A. = 0.87 sq. mi.)
Willett Ave. hydrograph
(D.A. = 1.31 sq. mi.)

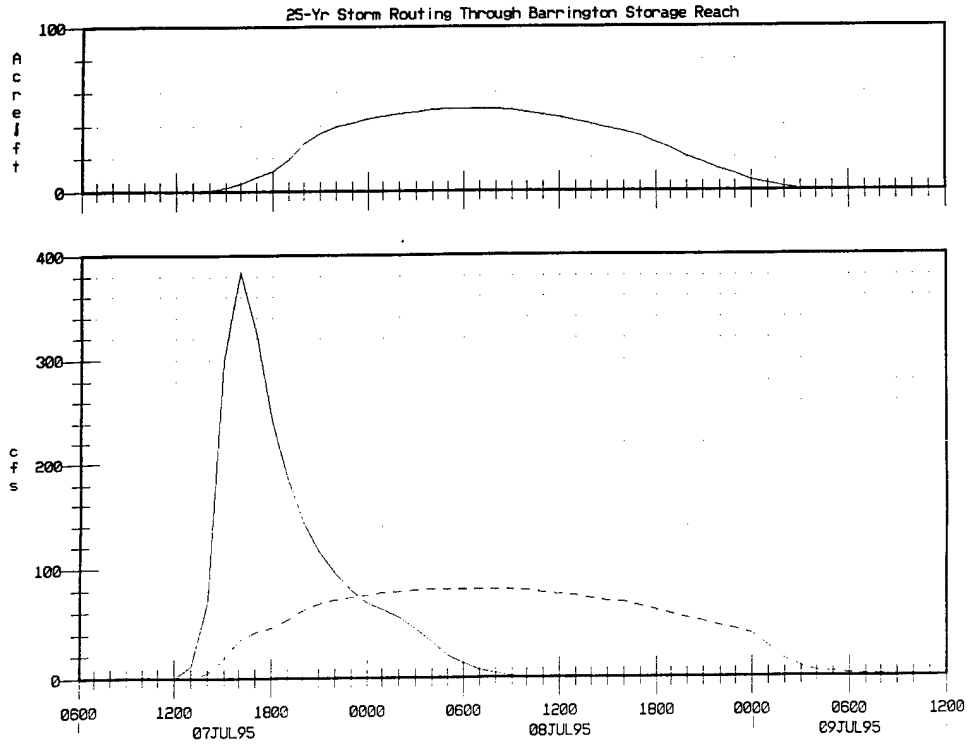

25-Yr Storm Routing Through Barrington Storage Reach
100
0
Acre ft
400
300
200
100
0
cfs
0600
1200
1800
0000
0600
1200
1800
0000
0600
1200
07JUL95
08JUL95
09JUL95
Inflow Hydrograph
Outflow Hydrograph
Storage

PLATE 3

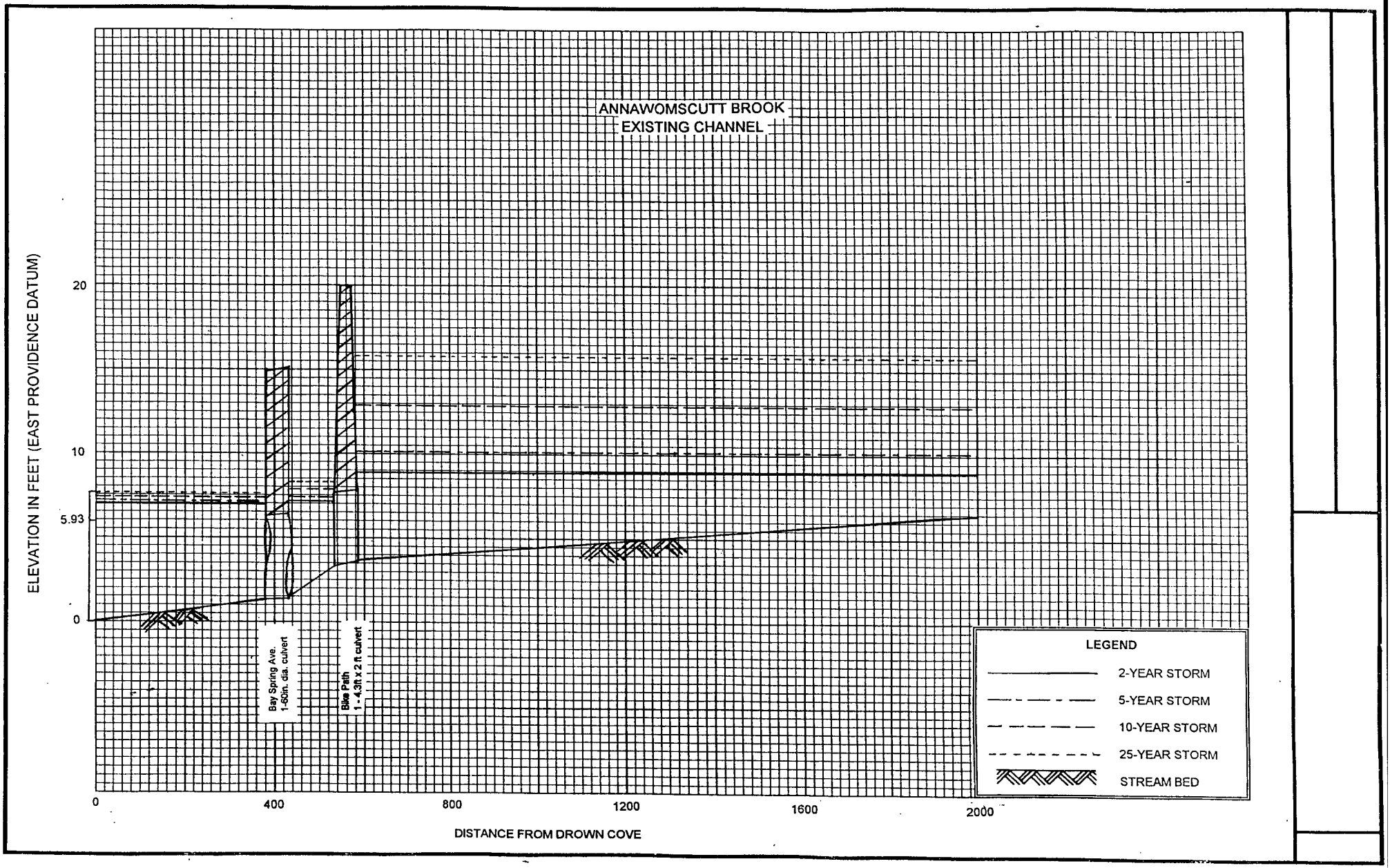

ANNAWOMSCUTT BROOK
EXISTING CHANNEL
ELEVATION IN FEET (EAST PROVIDENCE DATUM)
20
10
5.93
0
Bay Spring Ave.
1-60in. dia. culvert
Bike Path
1 - 4.3ft x 2 ft culvert
0
400
800
1200
1600
2000
DISTANCE FROM DROWN COVE
LEGEND
2-YEAR STORM
5-YEAR STORM
10-YEAR STORM
25-YEAR STORM
STREAM BED

PLATE 4A

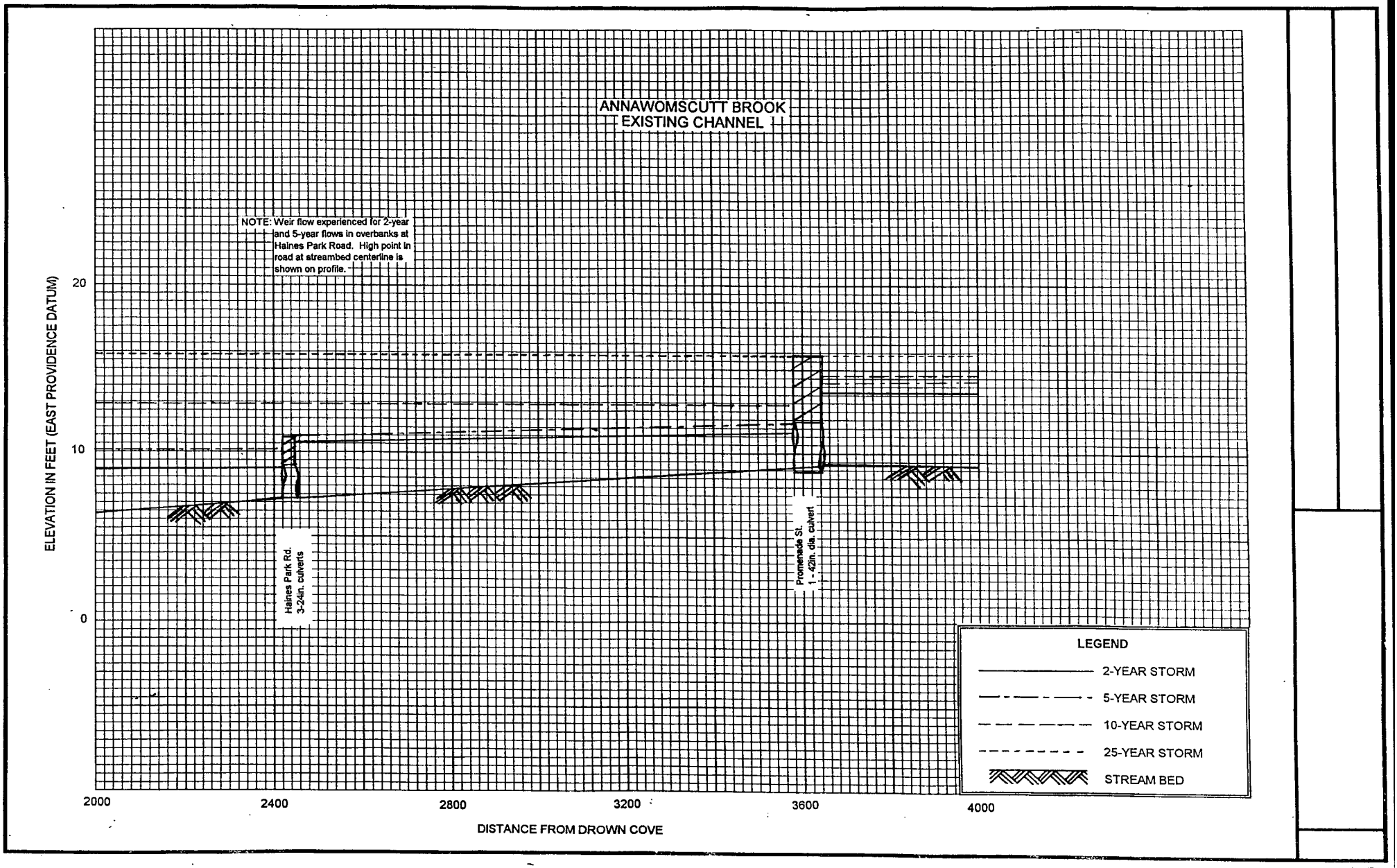

ANNAWOMSCUTT BROOK
EXISTING CHANNEL
NOTE: Weir flow experienced for 2-year and 5-year flows in overbanks at Haines Park Road. High point in road at streambed centerline is shown on profile.
ELEVATION IN FEET (EAST PROVIDENCE DATUM)
20
10
0
Haines Park Rd.
3-24in. culverts
Promenade St.
1 - 42in. dia. culvert
LEGEND
2-YEAR STORM
5-YEAR STORM
10-YEAR STORM
25-YEAR STORM
STREAM BED
2000
2400
2800
3200
3600
4000
DISTANCE FROM DROWN COVE

PLATE 4B

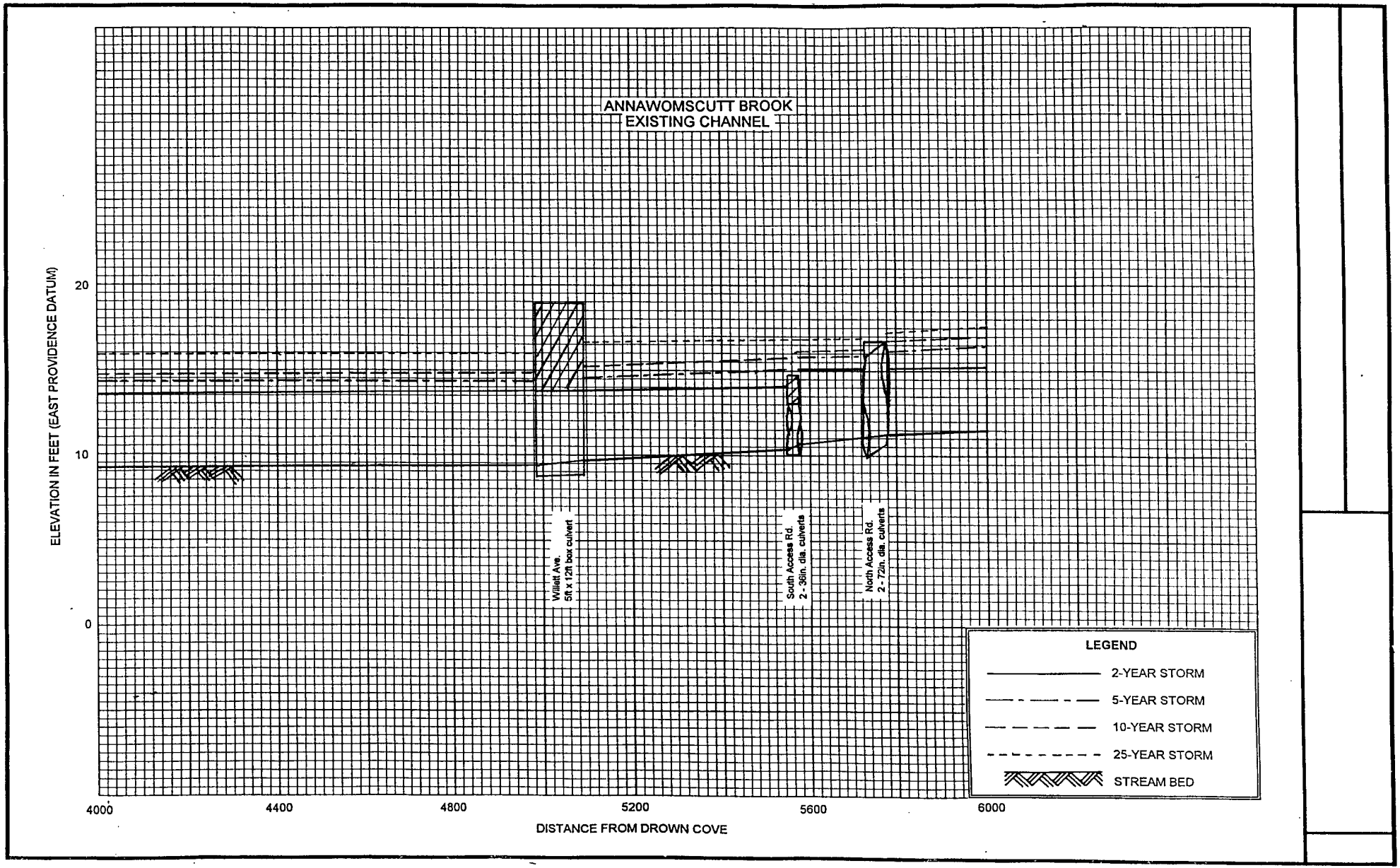

ANNAWOMSCUTT BROOK
EXISTING CHANNEL
ELEVATION IN FEET (EAST PROVIDENCE DATUM)
20
10
0
4000
4400
4800
5200
5600
6000
DISTANCE FROM DROWN COVE
Willett Ave.
5ft. x 12ft box culvert
South Access Rd.
2 - 36in. dia. culverts
North Access Rd.
2 - 72in. dia. culverts
LEGEND
2-YEAR STORM
5-YEAR STORM
10-YEAR STORM
25-YEAR STORM
STREAM BED

PLATE 4C

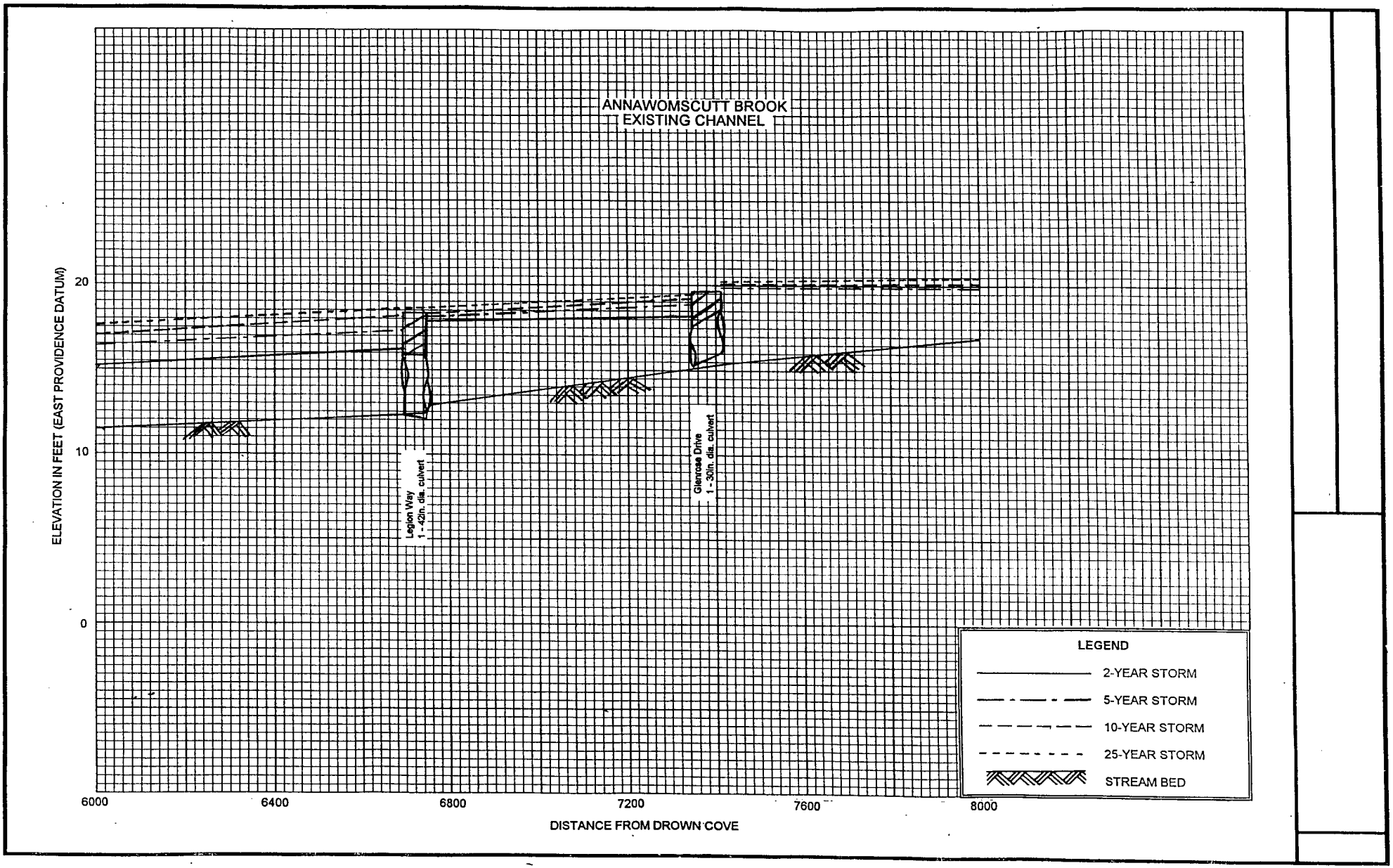

ANNAWOMSCUTT BROOK
EXISTING CHANNEL
ELEVATION IN FEET (EAST PROVIDENCE DATUM)
20
10
0
6000
6400
6800
7200
7600
8000
DISTANCE FROM DROWN COVE
Legion Way
1 - 42in. dia. culvert
Glenrose Drive
1 - 30in. dia. culvert
LEGEND
2-YEAR STORM
5-YEAR STORM
10-YEAR STORM
25-YEAR STORM
STREAM BED

PLATE 4D

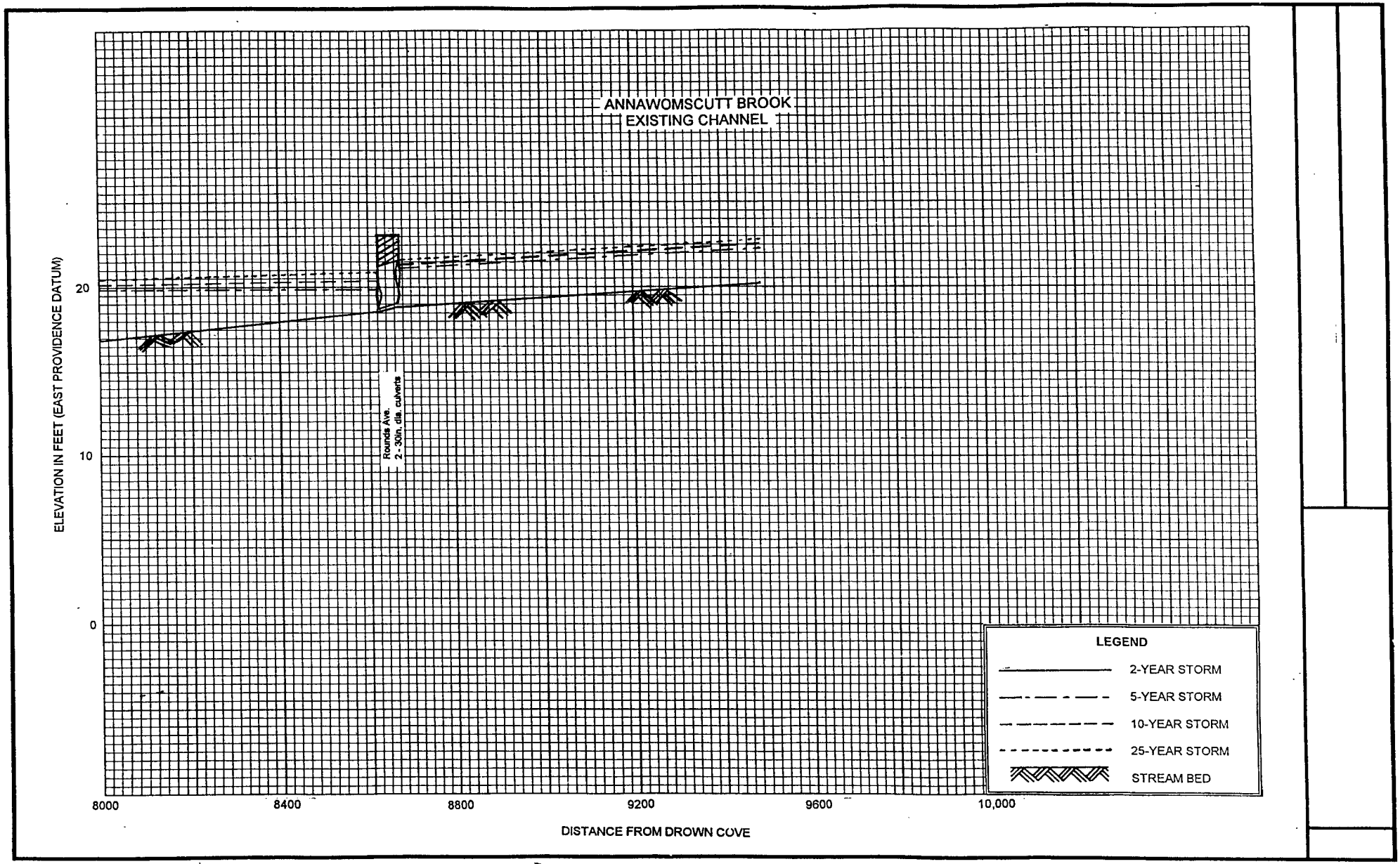

ANNAWOMSCUTT BROOK
EXISTING CHANNEL
Rounds Ave.
2 - 30in. dia. culverts
ELEVATION IN FEET (EAST PROVIDENCE DATUM)
20
10
0
8000
8400
8800
9200
9600
10,000
DISTANCE FROM DROWN COVE
LEGEND
2-YEAR STORM
5-YEAR STORM
10-YEAR STORM
25-YEAR STORM
STREAM BED

PLATE 4E

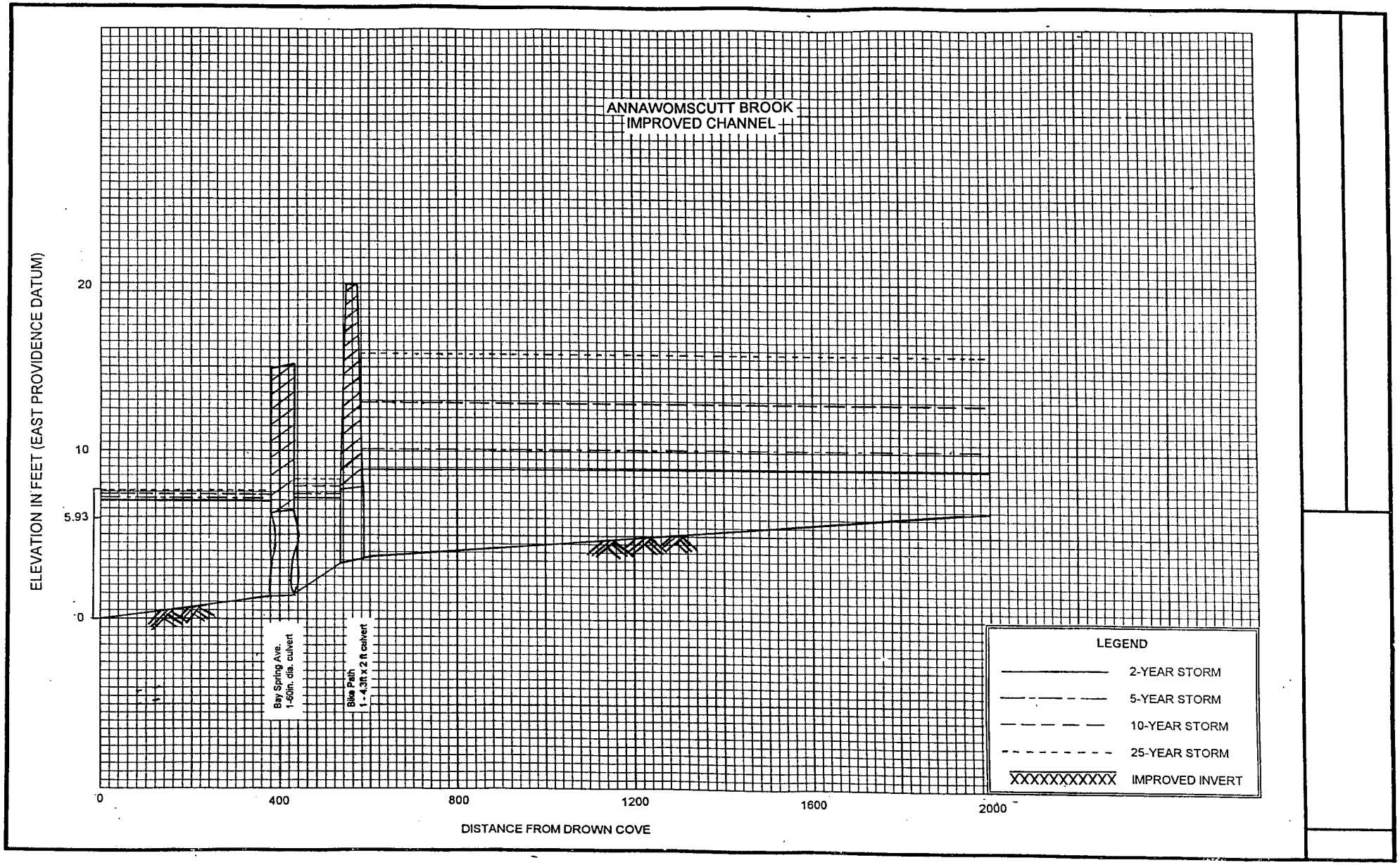

ANNAWOMSCUTT BROOK
IMPROVED CHANNEL
ELEVATION IN FEET (EAST PROVIDENCE DATUM)
20
10
5.93
0
Bay Spring Ave.
1-60in. dia. culvert
Bike Path
1 - 4.3ft x 2 ft culvert
0
400
800
1200
1600
2000
DISTANCE FROM DROWN COVE
LEGEND
2-YEAR STORM
5-YEAR STORM
10-YEAR STORM
25-YEAR STORM
IMPROVED INVERT

PLATE 5A

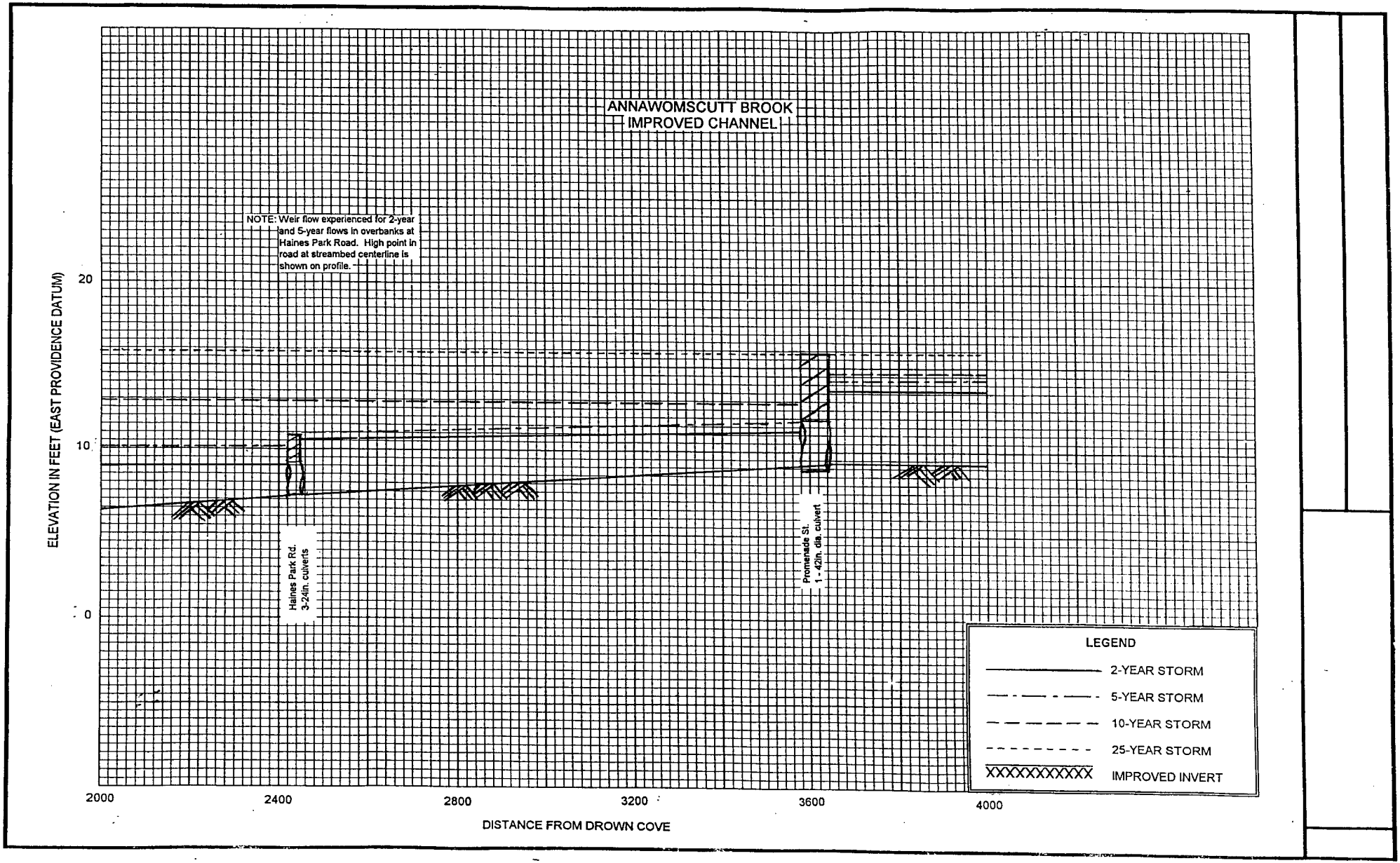

ANNAWOMSCUTT BROOK
IMPROVED CHANNEL
NOTE: Weir flow experienced for 2-year and 5-year flows in overbanks at Haines Park Road. High point in road at streambed centerline is shown on profile.
ELEVATION IN FEET (EAST PROVIDENCE DATUM)
20
10
0
Haines Park Rd. 3-24in. culverts
Promenade St. 1 - 42in. dia. culvert
LEGEND
2-YEAR STORM
5-YEAR STORM
10-YEAR STORM
25-YEAR STORM
IMPROVED INVERT
2000
2400
2800
3200
3600
4000
DISTANCE FROM DROWN COVE

PLATE 5B

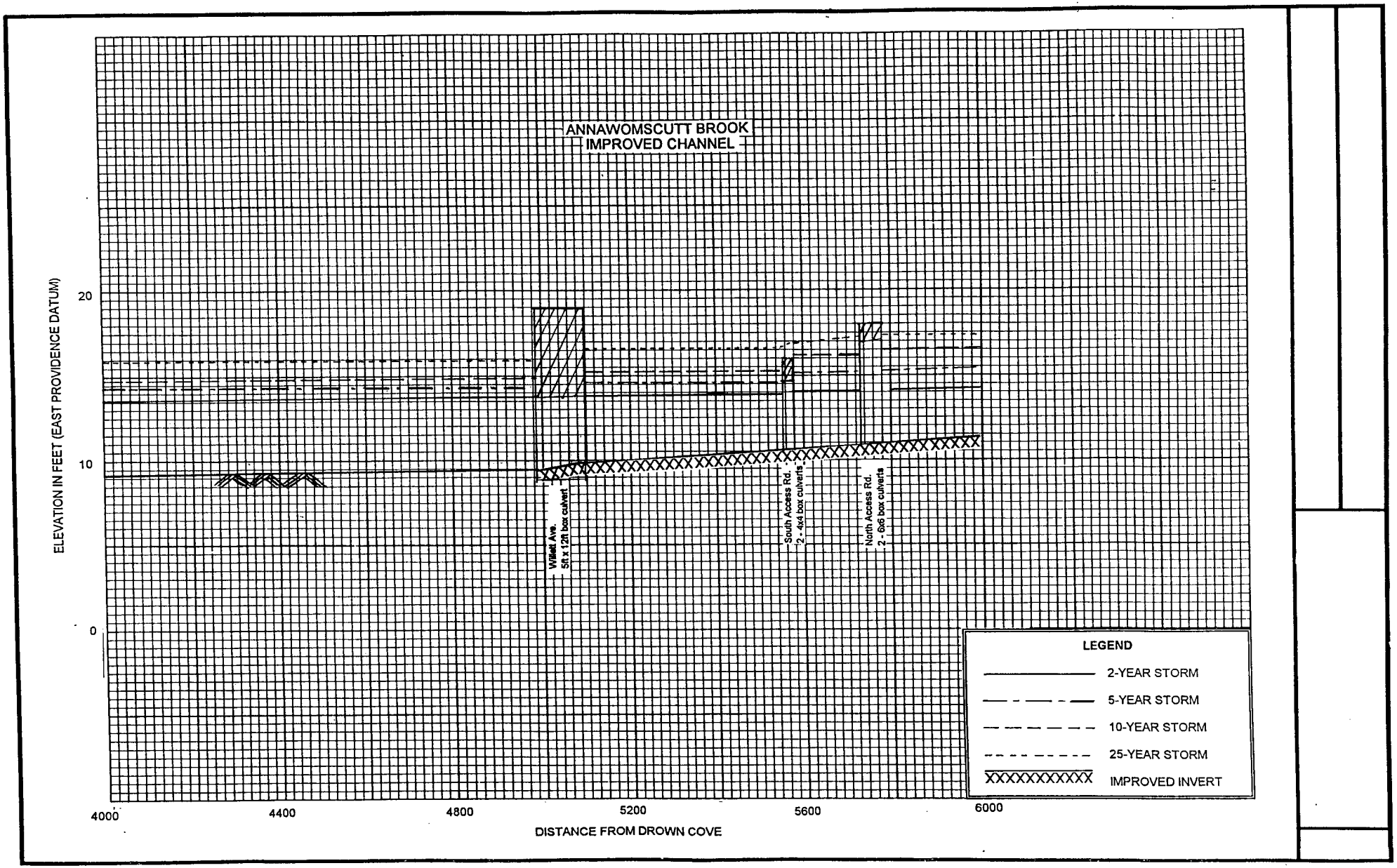

ANNAWOMSCUTT BROOK
IMPROVED CHANNEL
ELEVATION IN FEET (EAST PROVIDENCE DATUM)
20
10
0
4000
4400
4800
5200
5600
6000
DISTANCE FROM DROWN COVE
Willett Ave.
5ft x 12ft box culvert
South Access Rd.
2 - 4x4 box culverts
North Access Rd.
2 - 6x6 box culverts
LEGEND
2-YEAR STORM
5-YEAR STORM
10-YEAR STORM
25-YEAR STORM
IMPROVED INVERT

PLATE 5C

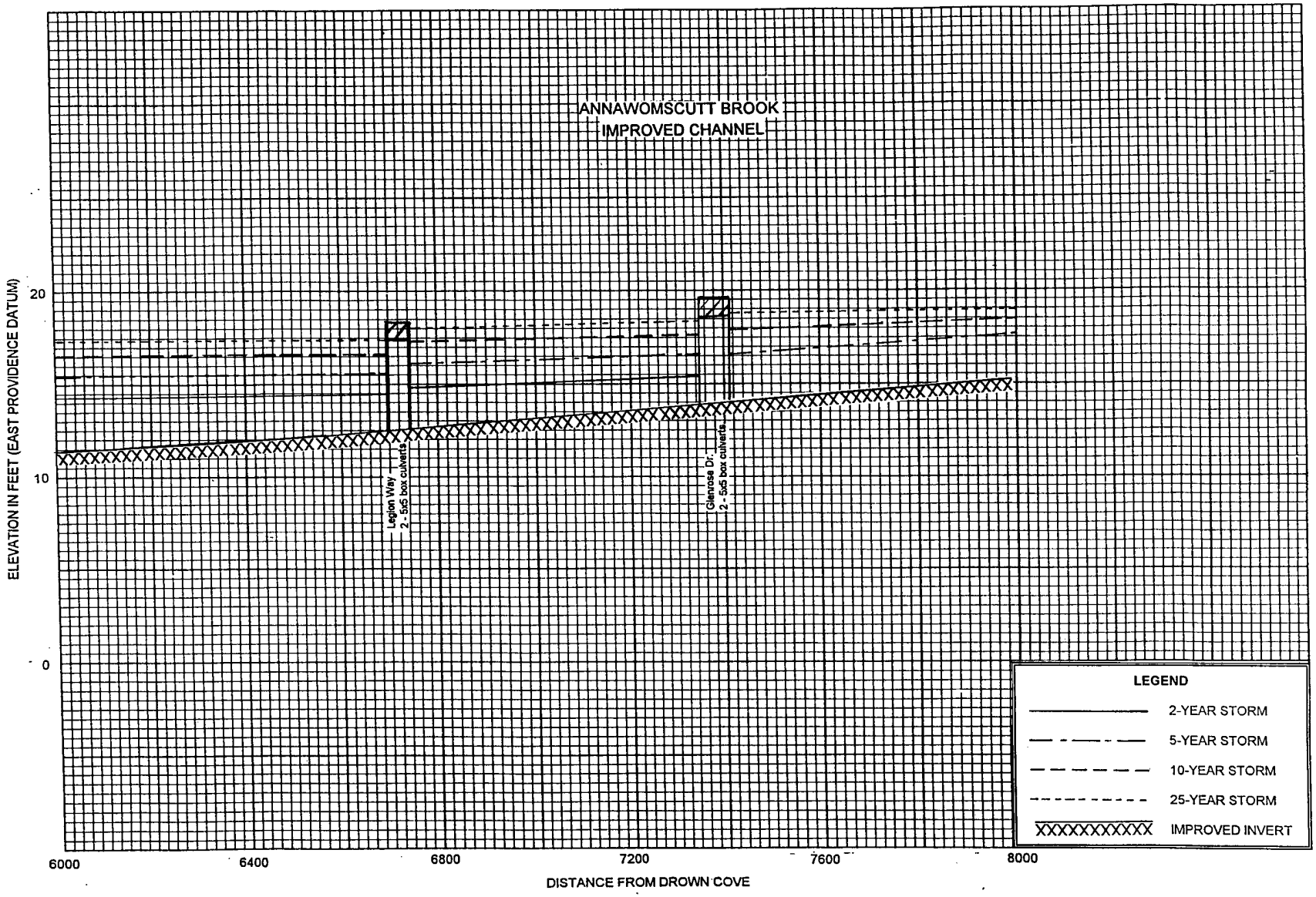

ANNAWOMSCUTT BROOK
IMPROVED CHANNEL
ELEVATION IN FEET (EAST PROVIDENCE DATUM)
20
10
0
Legion Way
2 - 5x5 box culverts
Glenrose Dr.
2 - 5x5 box culverts
6000
6400
6800
7200
7600
8000
DISTANCE FROM DROWN COVE
LEGEND
2-YEAR STORM
5-YEAR STORM
10-YEAR STORM
25-YEAR STORM
IMPROVED INVERT

PLATE 5D

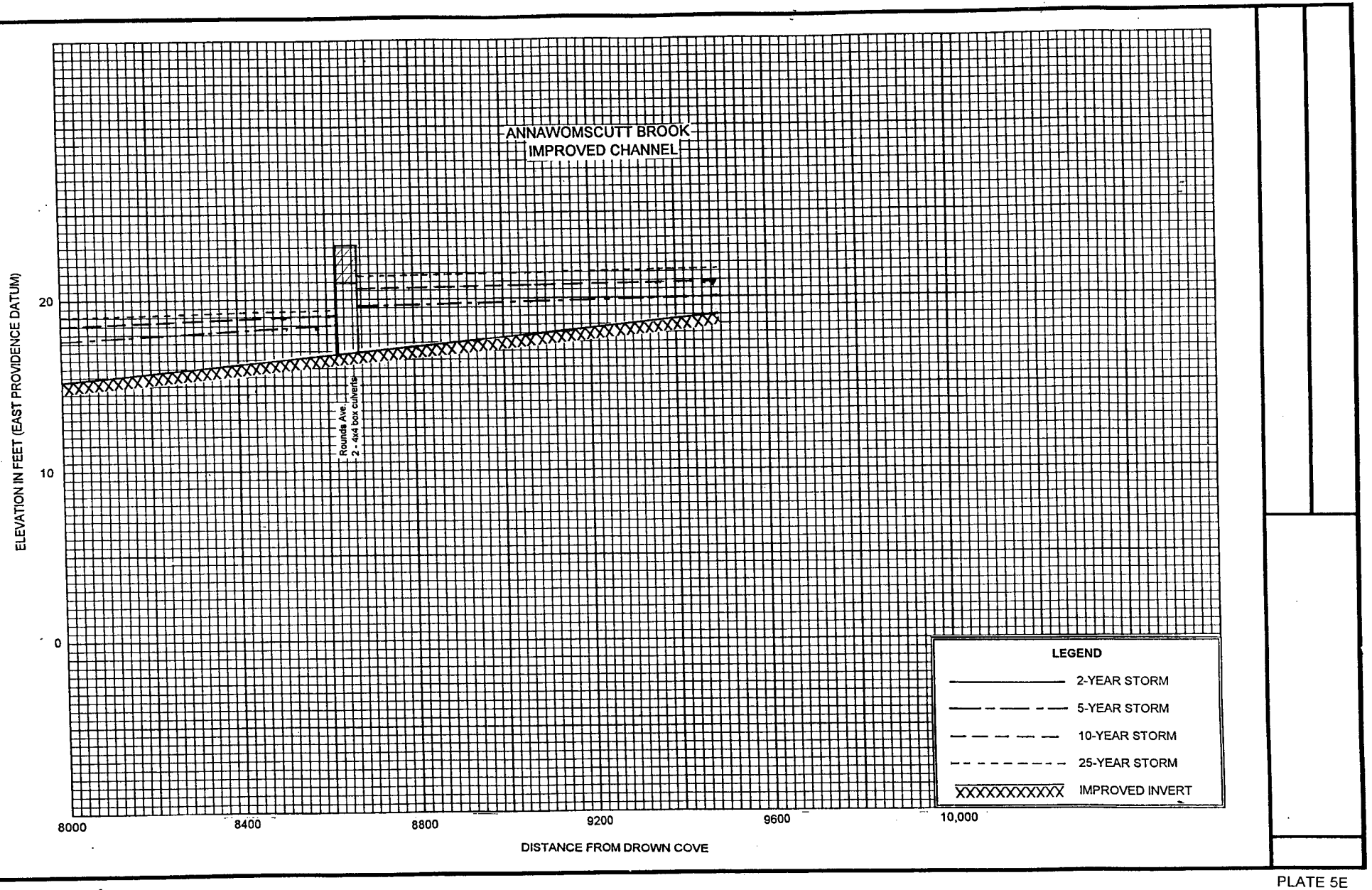

ANNAWOMSCUTT BROOK
IMPROVED CHANNEL
Rounds Ave.
2 - 4x4 box culverts
ELEVATION IN FEET (EAST PROVIDENCE DATUM)
20
10
0
8000
8400
8800
9200
9600
10,000
DISTANCE FROM DROWN COVE
LEGEND
2-YEAR STORM
5-YEAR STORM
10-YEAR STORM
25-YEAR STORM
IMPROVED INVERT

PLATE 5E

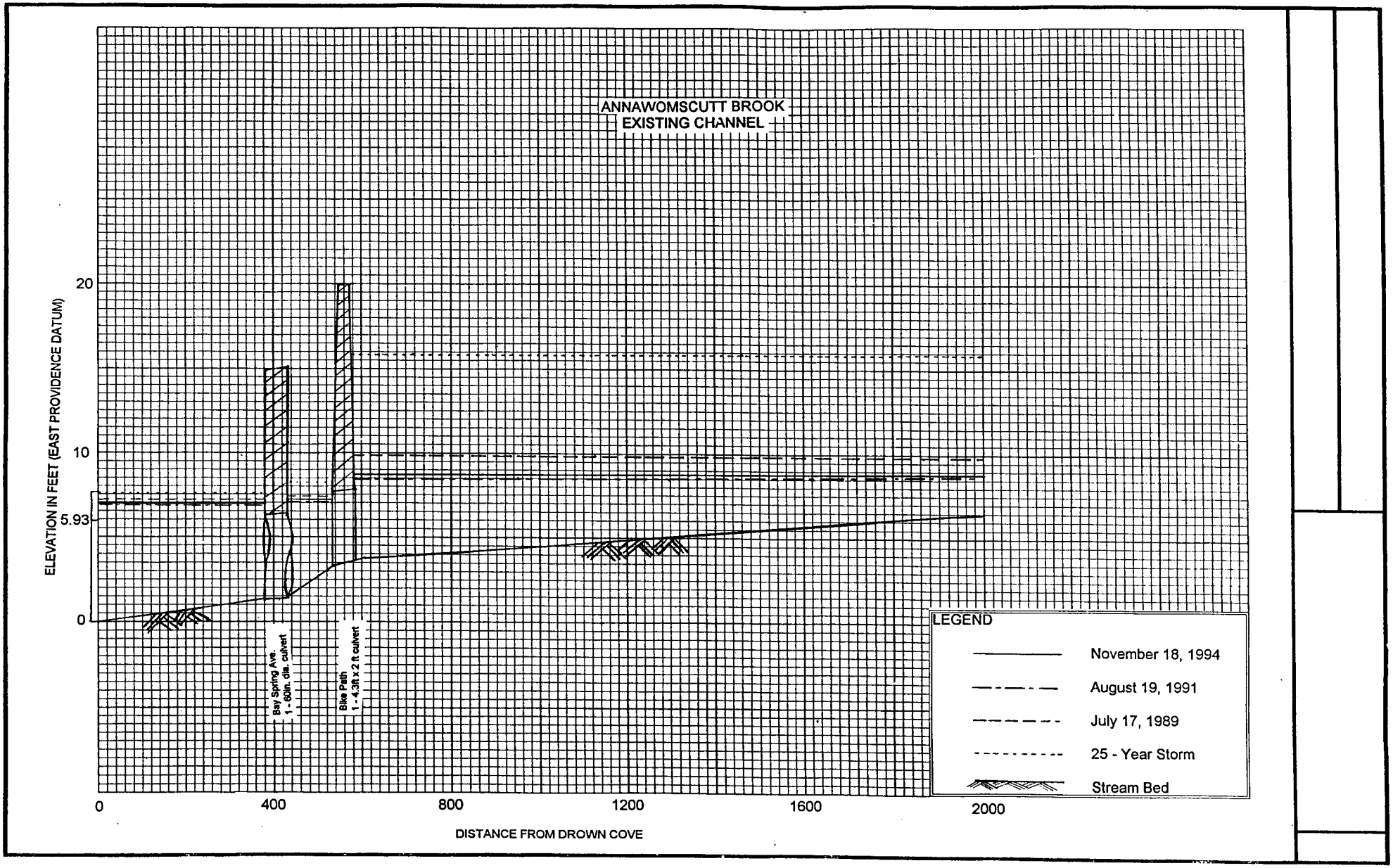

ANNAWOMSCUTT BROOK
EXISTING CHANNEL
ELEVATION IN FEET (EAST PROVIDENCE DATUM)
20
10
5.93
0
Bay Spring Ave.
1 - 60in. dia. culvert
Bike Path
1 - 4.3ft x 2 ft culvert
0
400
800
1200
1600
2000
DISTANCE FROM DROWN COVE
LEGEND
November 18, 1994
August 19, 1991
July 17, 1989
25 - Year Storm
Stream Bed

PLATE 6A

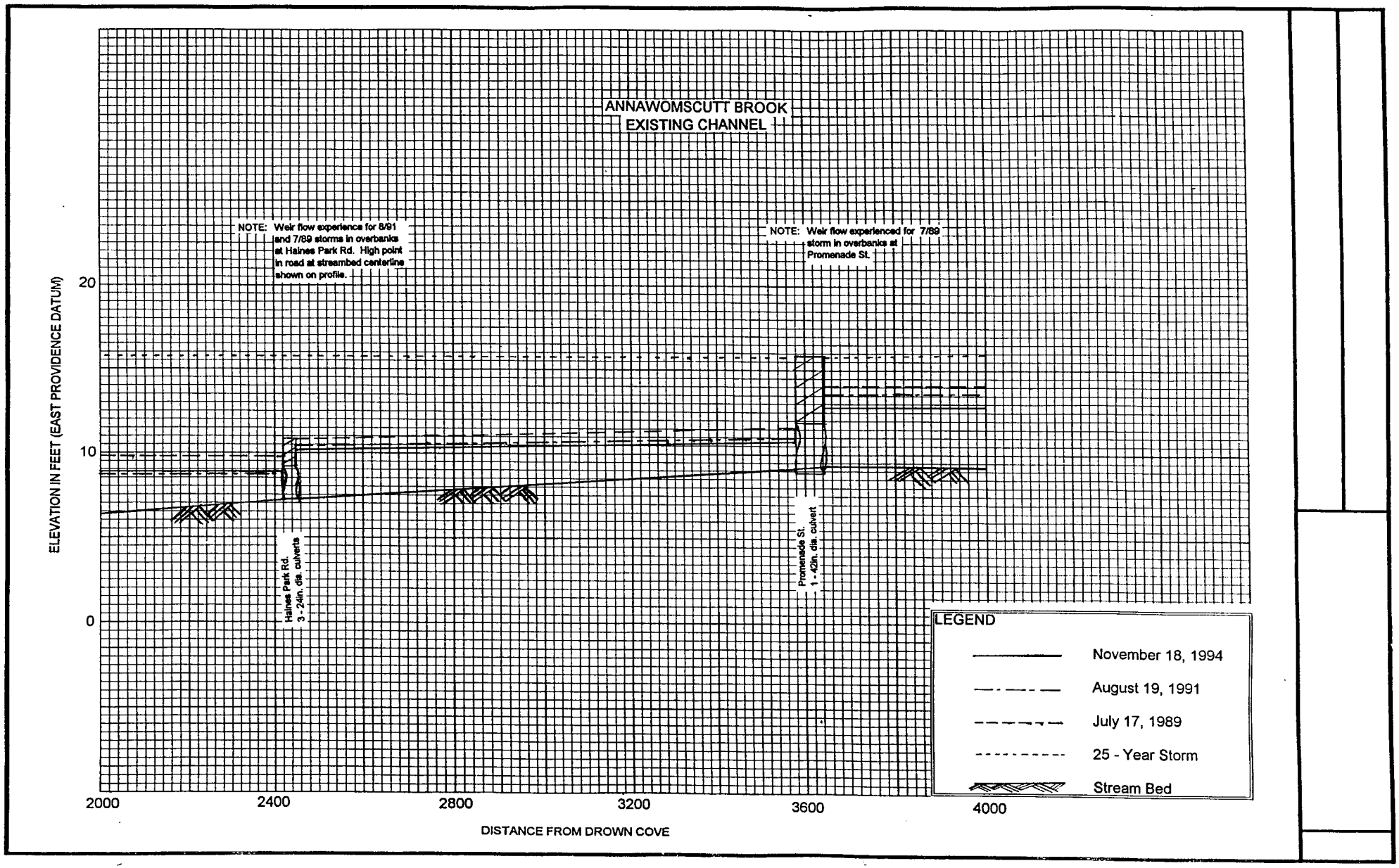

ANNAWOMSCUTT BROOK
EXISTING CHANNEL
NOTE: Weir flow experience for 8/91 and 7/89 storms in overbanks at Haines Park Rd. High point in road at streambed centerline shown on profile.
NOTE: Weir flow experienced for 7/89 storm in overbanks at Promenade St.
Haines Park Rd. 3 - 24in. dia. culverts
Promenade St. 1 - 42in. dia. culvert
LEGEND
November 18, 1994
August 19, 1991
July 17, 1989
25 - Year Storm
Stream Bed
ELEVATION IN FEET (EAST PROVIDENCE DATUM)
20
10
0
2000
2400
2800
3200
3600
4000
DISTANCE FROM DROWN COVE

PLATE 6B

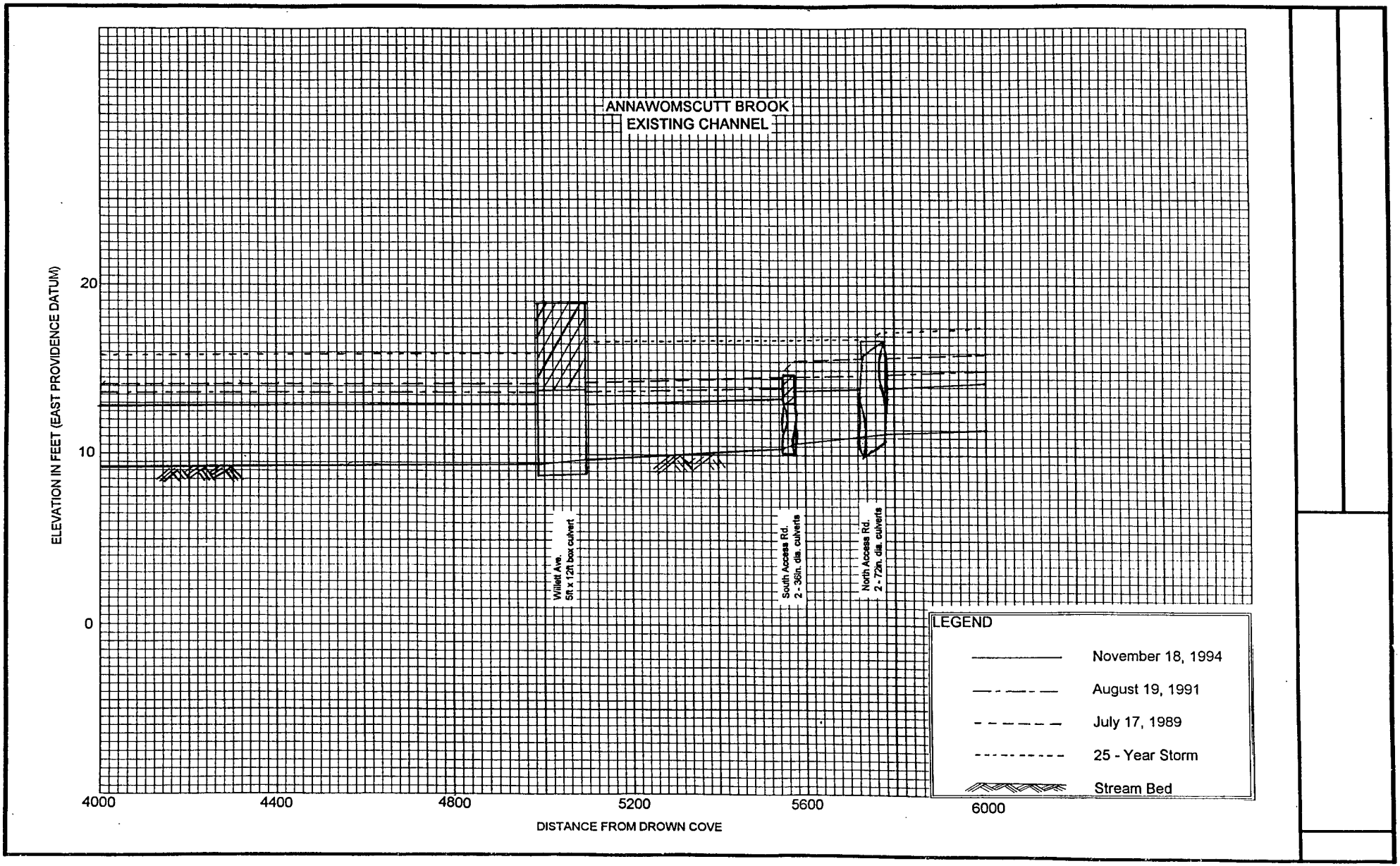

ANNAWOMSCUTT BROOK
EXISTING CHANNEL
ELEVATION IN FEET (EAST PROVIDENCE DATUM)
20
10
0
4000
4400
4800
5200
5600
6000
DISTANCE FROM DROWN COVE
Willett Ave.
5ft x 12ft box culvert
South Access Rd.
2 - 36in. dia. culverts
North Access Rd.
2 - 72in. dia. culverts
LEGEND
November 18, 1994
August 19, 1991
July 17, 1989
25 - Year Storm
Stream Bed

PLATE 6C

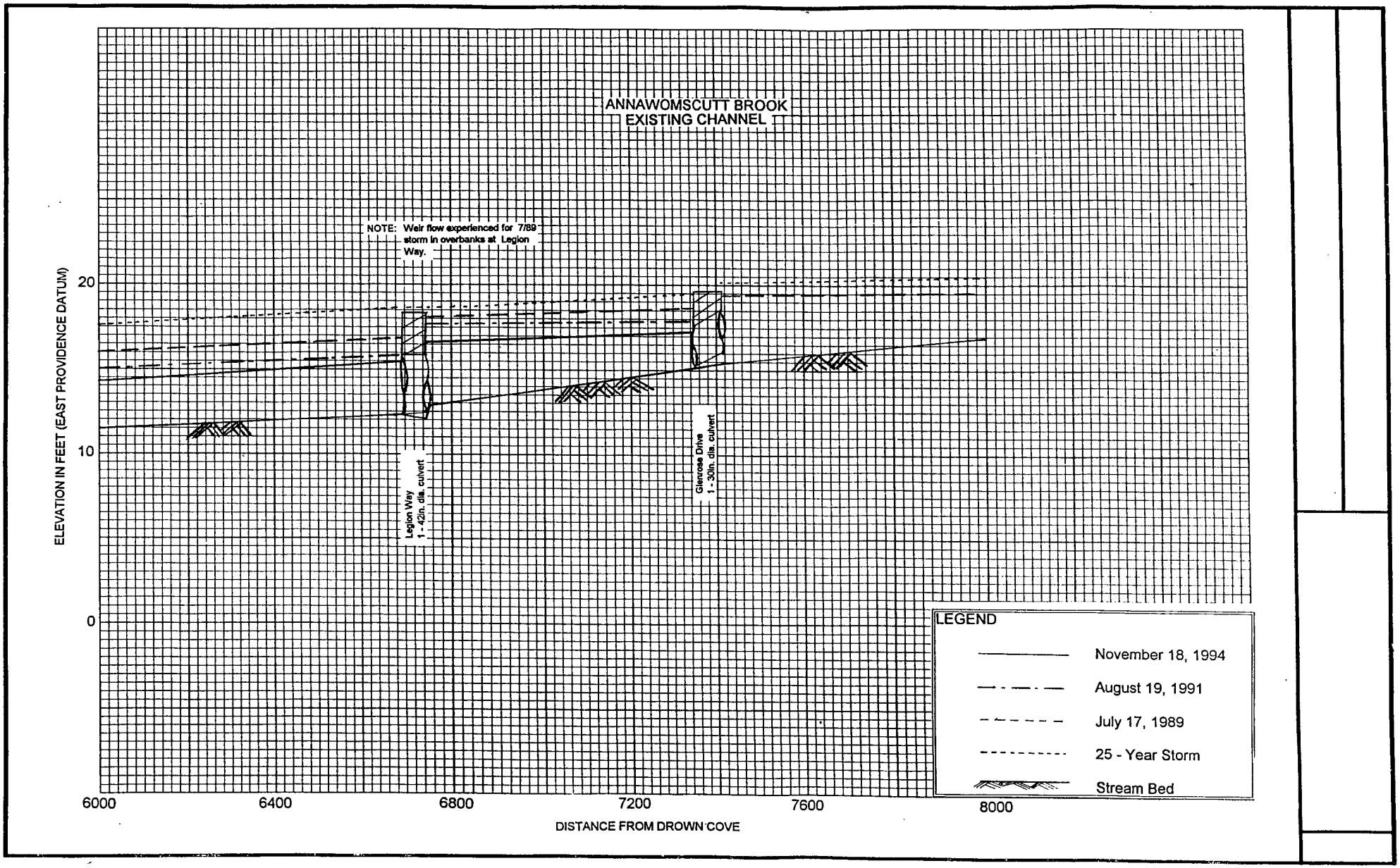

ANNAWOMSCUTT BROOK
EXISTING CHANNEL
NOTE: Weir flow experienced for 7/89 storm in overbanks at Legion Way.
Legion Way
1 - 42in. dia. culvert
Glenrose Drive
1 - 30in. dia. culvert
ELEVATION IN FEET (EAST PROVIDENCE DATUM)
20
10
0
6000
6400
6800
7200
7600
8000
DISTANCE FROM DROWN COVE
LEGEND
November 18, 1994
August 19, 1991
July 17, 1989
25 - Year Storm
Stream Bed

PLATE 6D

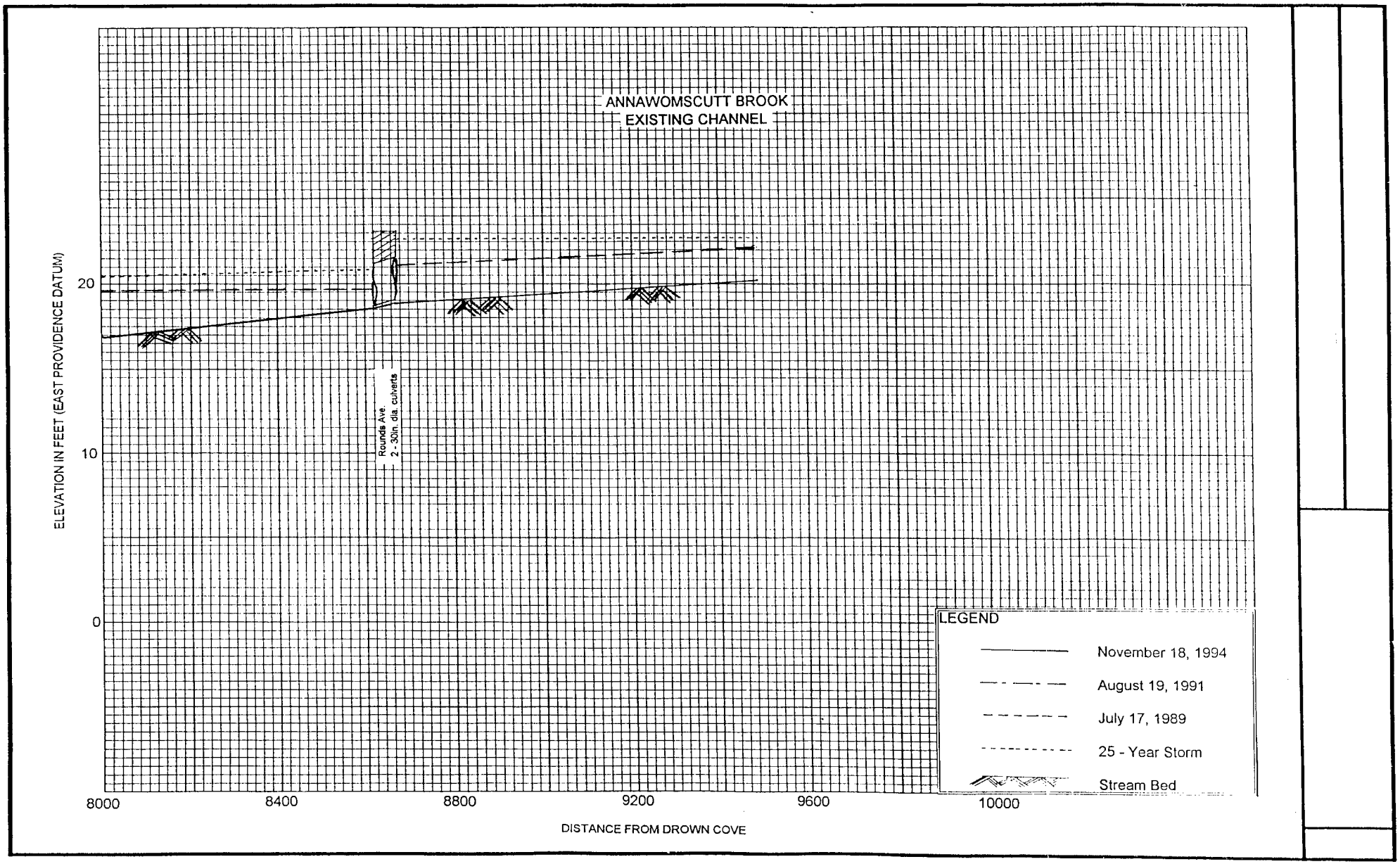

ANNAWOMSCUTT BROOK
EXISTING CHANNEL
Rounds Ave.
2 - 30in. dia. culverts
ELEVATION IN FEET (EAST PROVIDENCE DATUM)
20
10
0
8000
8400
8800
9200
9600
10000
DISTANCE FROM DROWN COVE
LEGEND
November 18, 1994
August 19, 1991
July 17, 1989
25 - Year Storm
Stream Bed

PLATE 6E

Appendix B - Culvert Descriptions

This section briefly describes some of the physical characteristics of the various culvert structures in East Providence and Barrington through which Annawomscutt Brook flows. These structures are culverts of varying sizes and material type. Included are photographs documenting their location and a brief description of their existing condition. Plates 2 & 3 show the locations of each of the culverts described in this section. The information presented here was derived from: (1) field investigations conducted in May 1995, (2) information obtained from previous reports, and (3) data provided by the City of East Providence.

General Culvert Description

City/Town: East Providence **Location:** Forbes Street

Over: Annawomscutt Brook

Culvert Type: ■ Round □ Box □ Arch □ Other _____

□ Corrugated Metal ■ Reinforced Concrete □ Stone Masonry □ Other_____

Number of Barrels: 1 **Size:** 30" **Length:** unknown

Culvert Invert Elevations: U/S unknown

D/S unknown

Streambed Invert Elevations: U/S unknown

D/S unknown

Waterway/Channel:

Upstream: Heavily vegetated wetlands area on Mobil Oil bulk storage facility.

Downstream: Channel continues through undeveloped land and the former Forbes Street landfill.

Culvert (Headwall, Barrel):

Trash rack/grate located at inlet of reinforced concrete pipe. No significant deterioration of pipe or deflection or settlement is apparent. Downstream outlet was not observed.

General Culvert Description

City/Town: East Providence **Location:** Rounds Avenue

Over: Annawomscutt Brook

Culvert Type: ■ Round □ Box □ Arch □ Other _____

■ Corrugated Metal □ Reinforced Concrete □ Stone Masonry □ Other_____

Number of Barrels: 2 **Size:** 30" **Length:** approx. 50'

Culvert Invert Elevations: U/S West 18.99'; East 19.06'

D/S West 18.68'; East 18.82'

Streambed Invert Elevations: U/S 18.80'

D/S 18.56'

Waterway/Channel:

Upstream: Good channel alignment with heavily vegetated slopes. This channel is a tributary to the main Annawomscutt Brook channel and rejoins the Brook just south of Glenrose Drive.

Downstream: Good channel alignment; channel invert and side slopes are paved with asphalt. Pavement appears to be in good condition. (See Photo 7) The asphalt lined channel continues for about 900' and ends south of Robin Hood Drive.

Culvert (Headwall, Barrel):

No significant sediment buildup in pipe inverts. There is only minor silt buildup in the west culvert pipe. There is no major corrosion or rust evident on either pipe, however, there appears to be some minor deflection of the east culvert barrel. Stone and mortar headwalls are in fair condition with some loose and missing mortar. It appears that the insides of culvert pipes were originally coated with asphalt. The majority of asphalt coating has either deteriorated or has broken up and is missing.

General Culvert Description

City/Town: East Providence **Location:** Rounds Ave. @ Tanglewood Dr.

Over: Annawomscutt Brook

Culvert Type: ■ Round □ Box □ Arch □ Other ____

□ Corrugated Metal ■ Reinforced Concrete □ Stone Masonry □ Other____

Number of Barrels: 1 **Size:** 48" **Length:** unknown

Culvert Invert Elevations: U/S 19.33'

D/S n/a

Streambed Invert Elevations: U/S 19.33'

D/S n/a

Waterway/Channel:

Upstream: Good channel alignment with heavy vegetation throughout drainage area. This channel is the main Annawomscutt Brook channel which enters the City's drainage network at this location.

Downstream: No downstream end. The brook enters the City drainage network and eventually discharges through two 36" pipes at Glenrose Drive.

Culvert (Headwall, Barrel):

Minor sediment buildup in pipe of about 1-2". Stone and mortar headwalls are in good condition with only some minor areas of missing mortar at the wingwall. A trash rack/grate is attached to the headwall. The pipes of the grate are corroded and bottom portions of the pipes are missing. (See Photo 5)

General Culvert Description

City/Town: East Providence **Location:** Glenrose Drive (west)

Over: Annawomscutt Brook

Culvert Type: ■ Round □ Box □ Arch □ Other _____

□ Corrugated Metal ■ Reinforced Concrete □ Stone Masonry □ Other_____

Number of Barrels: 1 **Size:** U/S 24"; D/S 30" **Length:** approx. 60'

Culvert Invert Elevations: U/S 16.02'

D/S 15.24'

Streambed Invert Elevations: U/S 15.45'

D/S 15.12'

Waterway/Channel:

Upstream: Good channel alignment; vegetated streambanks. Localized scour at pipe inlet (approx. 6"). This culvert carries flow from a tributary to the Annawomscutt Brook.

Downstream: Good channel alignment with localized scour at pipe outlet of approximately 5-7".

Culvert (Headwall, Barrel):

Stone/mortar headwall at upstream end has some loose stones and missing mortar. Concrete headwall at downstream end is in good condition. There are minor spalls and chipping of concrete pipe. There is no apparent settlement or deflection of the culvert. Approximately 70' downstream is the confluence of the main flow from Annawomscutt Brook which discharges from the drainage network. (See Photo 8)

General Culvert Description

City/Town: East Providence **Location:** Glenrose Drive (east)

Over: Annawomscutt Brook

Culvert Type: ■ Round □ Box □ Arch □ Other _____

□ Corrugated Metal ■ Reinforced Concrete □ Stone Masonry □ Other_____

Number of Barrels: 2 **Size:** 36" **Length:** unknown

Culvert Invert Elevations: U/S n/a

D/S West 14.37'; East 14.25'

Streambed Invert Elevations: U/S n/a

D/S West 15.12'; East 15.00'

Waterway/Channel:

Upstream: Upstream conditions are unknown because this culvert discharges from the City's stormwater pipe network.

Downstream: Fair channel alignment; meets with tributary channel approximately 70' downstream. (See Photo 9) Downstream on the west bank is a paved swale directing street runoff into the channel.

Culvert (Headwall, Barrel):

Streambed invert is about 9" above pipe invert. Concrete headwall and wingwall are in good condition. Stone/mortar headwall at upstream end has some loose stones and missing mortar. Concrete headwall at downstream end is in good condition. Note: Inside of culvert pipes not visible.

General Culvert Description

City/Town: East Providence **Location:** Legion Way

Over: Annawomscutt Brook

Culvert Type: ■ Round □ Box □ Arch □ Other ____

□ Corrugated Metal ■ Reinforced Concrete □ Stone Masonry □ Other____

Number of Barrels: 1 **Size:** 42" **Length:** approx. 50'

Culvert Invert Elevations: U/S 12.48'

D/S 12.31'

Streambed Invert Elevations: U/S 12.05'

D/S 12.31'

Waterway/Channel:

Upstream: Good channel alignment; vegetated streambanks. (See Photo 10)

Downstream: Heavy vegetation on both streambanks.

Culvert (Headwall, Barrel):

Stone/mortar headwalls and wingwalls are in fair condition with some minor spalling and cracking of mortar. (See Photo 11) No visible settlement or deflection of walls, culvert, or roadway. Downstream outlet was not observed due to inaccessibility. There is also an 18" diameter pipe discharging to the brook from the west bank just upstream from the culvert inlet. It appears this pipe drains the adjacent school property.

General Culvert Description

City/Town: East Providence **Location:** North Access Road (Almacs Parking Lot)

Over: Annawomscutt Brook

Culvert Type: ■ Round □ Box □ Arch □ Other ____

■ Corrugated Metal □ Reinforced Concrete □ Stone Masonry □ Other____

Number of Barrels: 2 **Size:** 72" **Length:** 41'

Culvert Invert Elevations: U/S 10.64'

D/S 9.86'

Streambed Invert Elevations: U/S East 11.30'; West (silted)

D/S East 11.23'; West (silted)

Waterway/Channel:

Upstream: Good channel alignment and heavy vegetation on streambanks. Inlet to west pipe heavily silted and appears to restrict normal flow. Heavy vegetation may also restrict flow during storm events. (See Photo 12)

Downstream: Heavy sediment buildup and vegetation at outlet of west pipe, similar to upstream end. Erosion of the east downstream bank has occurred at the top with the loss of pavement material. However, this condition appears to be due to surface runoff from the parking lot rather than streamflow conditions during rain events. There is heavy vegetation along both banks. Heavy vegetation prevented obtaining invert elevation of west culvert pipe. (See Photo 13)

Culvert (Headwall, Barrel):

Corrugated metal culverts appear to be in good condition with no visible indications of settlement or deflection of the east barrel. The interior of the west barrel was not visible.

General Culvert Description

City/Town: East Providence **Location:** South Access Road (Almacs Parking Lot)

Over: Annawomscutt Brook

Culvert Type: ■ Round □ Box □ Arch □ Other _____

■ Corrugated Metal □ Reinforced Concrete □ Stone Masonry □ Other_____

Number of Barrels: 2 **Size:** 36" **Length:** 22'

Culvert Invert Elevations: U/S East 10.06'; West 10.08'

D/S East 10.07'; West 10.07'

Streambed Invert Elevations: U/S 10.70'

D/S 10.42'

Waterway/Channel:

Upstream: Good channel alignment and heavy vegetation on streambanks.

Downstream: Good channel alignment and heavy vegetation on streambanks.

Culvert (Headwall, Barrel):

Headwalls and wingwalls constructed of stone masonry. Portions of both upstream and downstream headwalls have loose stones and settlement of stones in some areas. (See Photo 14) There appears to be no settlement or deflection of either pipe barrel. The west pipe is composed of two material types. The inlet is a corrugated metal pipe and the outlet is a concrete pipe. It is not apparent where this change of material type takes place within the overall length of the culvert.

General Culvert Description

City/Town: East Providence **Location:** Willett Ave. (Peck's Bridge)

Over: Annawomscutt Brook

Culvert Type: ☐ Round ■ Box ☐ Arch ☐ Other ____

☐ Corrugated Metal ■ Reinforced Concrete ☐ Stone Masonry ☐ Other____

Number of Barrels: 1 **Size:** 5'x12' **Length:** approx. 110'

Culvert Invert Elevations: U/S 8.82'

D/S 8.79'

Streambed Invert Elevations: U/S 9.67'

D/S 9.35'

Waterway/Channel:

Upstream: Good channel alignment and heavy vegetation on streambanks.

Downstream: Approx. 9" of sediment buildup in culvert and minor downstream scour of streambank. There is an abrupt change in channel alignment about 15' from culvert discharge. There is also storm drainage discharge from Willett Avenue catch basins through a 3.5' concrete pipe east of Annawomscutt Brook. There is about 10" of sediment buildup in this pipe.

(See Photo 15)

Culvert (Headwall, Barrel):

Isolated spalling of concrete and minor cracking in headwalls. No visible deflection or settlement of culvert. There is about 9" of sediment buildup in culvert with siltation along the west side of the barrel. There is also another drain pipe (diameter unknown) discharging into the west side of the box culvert near the upstream end. This pipe appears to drain the plaza parking lot.

General Culvert Description

City/Town: Barrington **Location:** Promenade Street

Over: Annawomscutt Brook

Culvert Type: ■ Round □ Box □ Arch □ Other _____

□ Corrugated Metal ■ Reinforced Concrete □ Stone Masonry □ Other_____

Number of Barrels: 1 **Size:** 42" **Length:** 67'

Culvert Invert Elevations: U/S 8.85' (silted)

D/S 8.99' (silted)

Streambed Invert Elevations: U/S 9.21'

D/S 9.07'

Waterway/Channel:

Upstream: Heavy vegetation on west bank, mowed grass (backyards) on east bank. No apparent embankment erosion. (See Photo 16)

Downstream: Some minor channel siltation about 20' downstream of outlet. No apparent embankment erosion.

Culvert (Headwall, Barrel):

Downstream headwall of stone and mortar in fair condition. There is no upstream headwall. There is no apparent settlement or deflection of the visible portions of this reinforced concrete culvert. There is approximately 7" of silt buildup at the upstream inlet of the culvert.

General Culvert Description

City/Town: Barrington **Location:** Haines Park Road

Over: Annawomscutt Brook

Culvert Type: ■ Round □ Box □ Arch □ Other ____

■ Corrugated Metal □ Reinforced Concrete □ Stone Masonry □ Other____

Number of Barrels: 3 **Size:** 24" **Length:** 34.5'

Culvert/Streambed Invert Elevations: U/S East 7.27'; Middle 7.25'; West 7.31'

D/S East 7.07'; Middle 7.13'; West 7.17'

Waterway/Channel:

Upstream: Heavily vegetated on both upstream banks. (See Photo 18) No channel scour or embankment erosion. Channel does not align with very well with the west culvert.

Downstream: West bank mowed lawn area. East bank contains heavy vegetation. Channel continues through undeveloped park land and widens until reaching two ponds just north of Bay Spring Avenue. (See Photo 20)

Culvert (Headwall, Barrel):

No significant deterioration of pipe or deflection or settlement is apparent. Minor silt buildup (1-2") at upstream end of center culvert. (See Photo 19)

General Culvert Description

City/Town: Barrington **Location:** Bike Path

Over: Annawomscutt Brook

Culvert Type: ☐ Round ■ Box ☐ Arch ☐ Other _____

☐ Corrugated Metal ☐ Reinforced Concrete ■ Stone Masonry ☐ Other_____

Number of Barrels: 1 **Size:** 4'x4' **Length:** Unknown

Culvert/Streambed Invert Elevations: U/S 3.55'

D/S 3.40'

Waterway/Channel:

Upstream: Ponded area between Haines Park Road and the bike path. (See Photo 21)

Downstream: Ponded area between bike path and Bay Spring Avenue.

Culvert (Headwall, Barrel):

Culvert barrel was not visible. Headwalls are stone masonry in fair condition.
(See Photo 22)

General Culvert Description

City/Town: Barrington **Location:** Bay Spring Avenue

Over: Annawomscutt Brook

Culvert Type: ■ Round □ Box □ Arch □ Other _____

■ Corrugated Metal □ Reinforced Concrete □ Stone Masonry □ Other_____

Number of Barrels: 1 **Size:** 60" **Length:** Unknown

Culvert/Streambed Elevations: U/S 1.46'

D/S 1.29'

Waterway/Channel:

Upstream: Pond between Bay Spring Avenue and the bike path. (See Photo 23)

Downstream: Similar to upstream area. Large pond created by downstream dam at outlet to Drown Cove.

Culvert (Headwall, Barrel):

Upstream and downstream headwall is a stone and mortar structure in fair condition. General condition of the culvert is unknown due to inaccessibility of site.

Appendix C

Scope of Studies

Southeast Area Drainage District
East Providence, Rhode Island

Section 206
Flood Plain Management
Services (FPMS) Program

I. Introduction:

a. Authority

The Corps of Engineers was requested by the City of East Providence, Rhode Island to conduct an investigation of flooding problems due to surface water and high groundwater levels in the City's Southeast Area Drainage District. However, this study will focus only on flooding problems associated with surface water. This study will be conducted under the Corps of Engineers' Flood Plain Management Services (FPMS) program. The FPMS program is authorized under Section 206 of the Flood Control Act of 1960 (PL-86-645). This program allows the Corps to provide planning and technical assistance relating to flooding and flood plain management.

b. Study Purpose and Scope

The purpose of this study is to evaluate existing and potential flooding along the Annawomscutt Brook and provide recommendations relative to alleviating those problems.

A study conducted for the city in 1981 by Camp Dresser & McKee (CDM), Inc., (Southeast Area Drainage District Report On Drainage Improvements, June 1981) outlined a series of recommendations to address the immediate and most severe street and basement flooding within this area. The information, conclusions, and findings contained in the CDM study will be utilized, to the extent possible, for this investigation.

The CDM study provided specific recommendations for each sub-watershed within the Southeast Area Drainage District. Some of the recommended improvements have been completed by the City, however, they have not implemented the recommended improvements to Annawomscutt Brook.

Therefore, the City has requested that further recommended drainage improvements, as

detailed in the CDM report, be reevaluated for their effectiveness in mitigating flooding problems within this area. In particular, the City desires a hydraulic analysis of Annawomscutt Brook and the proposed CDM improvements to the brook.

This study will be coordinated with all appropriate Federal, State, Municipal and other interested parties. Areas of additional study will also be identified, if necessary.

II. Project Tasks

a. Problem Identification

Evaluate surface water flooding problems experienced within the Southeast Area Drainage District which are related to Annawomscutt Brook. This will likely include reviewing data collected by CDM in 1980, and collecting information from local officials and residents. This will provide an indication of flooding problems and their locations and will also determine specific areas of recurring street and basement flooding in the watershed.

b. Hydrologic/Hydraulic Analysis

A hydrologic/hydraulic analysis of the Annawomscutt Brook watershed will be accomplished to determine peak flows, hydrographs, and the extent of flooding for two or three rainfall events. The major tasks associated with the hydrologic/hydraulic analysis of Annawomscutt Brook are defined below.

1. Develop hydrologic and hydraulic models which represent the existing condition of the brook and watershed. Modelling will need to address both channel and culvert flow. The model should extend sufficiently downstream to adequately identify adverse impacts in East Providence.

2. Develop appropriate design flows by use of a rainfall-runoff model and identify areas with flooding problems after development of a hydraulic model (HEC-2). This data can then be compared with the flooding information in task "a." above.

3. Modify the existing conditions models to represent improvements proposed in the CDM study and run the modified models for the storms selected in task "b.2." above.

4. Evaluate the hydraulic capacity of the channel to convey both existing flows and flows associated with the proposed CDM improvements.

5. Identify and evaluate possible corrective measures in the channel configuration to improve its conveyance capacity for both the existing conditions and for the proposed CDM improvements.

c. Findings and Recommendations

Findings of the study tasks will be outlined and recommendations for channel modifications (with preliminary cost estimates) to Annawomscutt Brook will be made.

d. Coordination, Project Management, & Report Preparation

The results of this analysis will be coordinated with appropriate Federal, State, and local agencies to obtain their views. The results of the study will be summarized in a report and additional studies will also be identified, if necessary.

III. Report Documentation

A report will be submitted to the City of East Providence in draft form for comment and review. Upon resolution of provided comments, the New England Division will prepare and issue a final report.

IV. Project Coordination

This study will be conducted by the New England Division of the Corps of Engineers. The New England Division will coordinate with the City of East Providence on all issues concerning the study which deviate from the original Scope of Studies. The New England Division will maintain coordination with all appropriate Federal, State, and local agencies throughout the study.

V. Project Cost and Completion Schedule

It has been determined that the Southeast Area Drainage District study will cost $40,000 and will be completed within 12 months.